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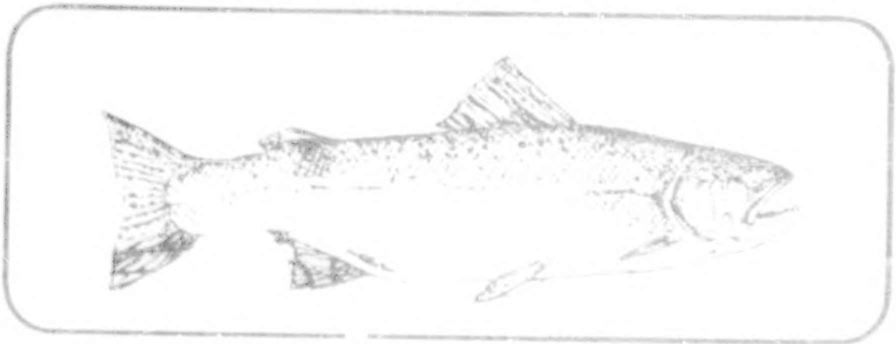
Energy Related Use Conflicts for the Columbia River Estuary

Volume I
Text



U.S. ENVIRONMENTAL PROTECTION AGENCY
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FWS/OBS-82/60
June 1983

ENERGY RELATED USE CONFLICTS FOR THE COLUMBIA RIVER ESTUARY

VOLUME I
TEXT

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PREFACE

The Columbia River system probably has been physically altered more than any waterway in the United States. A number of dams on the main stream and some on the tributaries have changed water levels and flow, and water temperature and turbidity throughout the system. Further alteration, especially in the lower Columbia River and to a lesser degree to the estuary, is expected if the construction and operation of fossil-fueled electric power plants and oil refineries, and the transportation of oil and coal, are significantly accelerated.

This report has two volumes. Volume 1 provides a narrative description of projected energy development and describes the biological characteristics of fish and wildlife and their habitats, and gives a critique of potential environmental impacts, and measures of protection and mitigation.

Volume 2 is a series of 13 maps or quadrants of the lower Columbia River and estuary showing the location of energy-related use conflicts projected at five, fifteen, and twenty-five year intervals. Each quadrant is a scenario of low, medium, and high (or their combination) levels of energy-related developments.

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LIST OF ACRONYMS

ASCE	American Society of Civil Engineers
BLM	Bureau of Land Management
BOD	Biological Oxygen Demand
BPA	Bonneville Power Administration
BSAI	BioSystems Analysis, Inc.
BWR	Boiling Water Reactor
CDC	California Department of Conservation
CDH	Colorado Division of Highways
CEC	California Energy Commission
CEIP	Coastal Energy Impact Program
CEQ	Council of Environmental Quality
CFR	Code of Federal Regulations
CPCR	An Ecological Characterization of the Pacific Northwest Coastal Region - See Proctor et al. 1980
CREDDP	Columbia River Estuary Data Development Program
CREST	Columbia River Estuary Study Team
CRFC	Columbia River Fisheries Council
CZM	Coastal Zone Management
CZMA	Coastal Zone Management Act
DED	Department of Economic Development
DFOC	Department of Fisheries and Oceans, Canada
DNR	Department of Natural Resources
DSL	Division of State Lands
ECPA	Environmental Coordination Procedures Act
EFSC	Energy Facility Siting Council
EFSEC	Energy Facility Site Evaluation Council
EIS	Environmental Impact Statement
EPRI	Electric Power Research Institute
ERDA	U.S. Energy Research and Development Administration
FERC	U.S. Federal Energy Regulatory Commission
GPP	Gross Primary Production
HSM	Hypothesis Systems Models
JTU	Jackson's Turbidity Units
LASH	Lighter Aboard Ship
LCDC	Land Conservation and Development Commission
LNG	Liquified Natural Gas
LPG	Liquified Petroleum Gas
MW	Megawatts
NEPA	National Environmental Protection Act
NEPP	Northwest Energy Policy Project
NESP	National Environmental Studies Project
NPDES	National Pollution Discharge Elimination System
NRDC	Natural Resources Defense Council
NPPC	Northwest Power Planning Council
OCS	Outer Continental Shelf
ODFW	Oregon Department of Fish and Wildlife
ODWR	Oregon Department of Water Resources
OECD	Organization for Economic Cooperation and Development

LIST OF ACRONYMS (Continued)

OIW	Oceanographic Institute of Washington
OPD	Oregon Ports Division
OPI	Oregon Production Index
ORNL	Oak Ridge National Laboratories
ORV	Off-Road Vehicle
OSU	Oregon State University
OTA	Office of Technological Assessment
PGE	Portland Gas and Electric
PNUCC	Pacific Northwest Utilities Conference Commission
PNRC	Pacific Northwest Regional Commission
PPC	Pacific Power and Light
PUD	Public Utility District
PWR	Pressurized Water Reactor
ROW	Right-of-Way
SAI	Science Applications Inc.
SEPA	State Environmental Policy Act
USDA	U.S. Department of Agriculture
USDI	U.S. Department of Interior
USEPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Services
USGS	U.S. Geological Services
WDF	Washington Department of Fisheries
WDOE	Washington Department of Ecology
WPPSS	Washington Public Power Supply System
WPRS	Water and Power Resources Services
WRPA	Water Resources Planning Act

SUMMARY

INTRODUCTION AND OBJECTIVES OF THE STUDY

This study of the Energy Related Use Conflicts for the Columbia River Estuary is intended to identify and describe factors important to fish and wildlife managers that are confronted with energy development in sensitive habitat areas. The study encompasses projection and mapping of energy related developments in the estuary and lower river, summarization of development impacts upon fish and wildlife in estuarine systems, modeling of developments in six estuarine ecosystems, detailed accounts of valuable estuarine species, a log of site-specific conflicts by river mile, a cumulative impact summary, definition of planning, policy, and regulatory processes for development, and characterization of management and mitigation practices applicable to specific species and to generic types of energy facilities.

When fish and wildlife managers must make long-term decisions regarding habitat and species conservation, an integrated overview of ecosystems and human systems in the locale of concern is needed. This study is designed to provide, for the Columbia River Estuary, the temporal and spatial dimensions of anticipated development, the ecosystem components affected, particularly the species at risk, the tools available to influence impacts, and the human-system processes which control development. An understanding of all of these is necessary for fish and wildlife managers to develop appropriate responses to the complex issues posed by development in and near an estuary of a major river.

The specific objectives of the study, as defined by the U.S. Fish and Wildlife Service (USFWS), are: to forecast energy development and related activities in and near the Columbia River Estuary; to apply the principles of the Ecological Characterization of the Pacific Northwest Coastal Region (CPCR) report to the Columbia River Estuary and its fish and wildlife resources; to identify fish and wildlife conflicts of proposed energy development in the estuary; to assess the impacts of energy development on estuarine fish and wildlife resources; to prescribe measures by which environmental conflicts can best be resolved and losses can best be mitigated; and to define data gaps and research needs for streamlining and updating research and surveys for practical application to fish and wildlife management problems.

COLUMBIA RIVER AND ESTUARY

The Columbia River drains a basin encompassing territory in seven western states and two Canadian provinces (Frontisepiece), and forms the largest estuary in the Pacific Northwest. It is the largest river on the West Coast of North America, and, together with its tributaries, is the dominant water sources system of the Pacific Northwest.

The Columbia River Estuary serves as the entrance point to an extensive inland navigation system. Its entrance and interior channels extend deep-draft service 106 miles upstream to Vancouver, and, by means of locks and reservoirs, shallow draft service upstream to Pasco on the Columbia River and to the Idaho-Washington border on the Snake River. The various ports handle large quantities of grain, wood products, chemicals, and ores. A large part of the petroleum products used in the area are brought into the Columbia River by deep draft tankers and are distributed by barge, train, and truck into the interior.

Upstream, the Columbia and Snake rivers have been intensively developed for hydroelectric power production. Existing Columbia River system projects, including Canadian storage, permit regulation such that monthly flows range from 130,000 to 500,000 cfs. Seasonal flow regulation for power production generally is made compatible with river uses for flood control, navigation, and irrigation, and is partly constrained by water requirements for recreation and fish. Short-term regulation is partly constrained by releases required for existing water rights, water quality, navigation, fish, and recreation, and by limitations on river and pool level fluctuations. If thermal generation assumes an increasing larger base load share and hydro installations are operated more for peaking hourly stream flow, fluctuations will increase. Reregulating facilities have been installed at some projects to permit full peaking potential development without causing unacceptable downstream water flow and level fluctuations. Extensive small hydroelectric development is proposed for small tributaries within the Columbia Basin and could exacerbate existing effects.

The role of the Columbia River in providing access, safe harbor, transportation, electric power, flood control, irrigation and industrial water supply, as well as aesthetic, fish, and wildlife values, creates a very complex situation for fish and wildlife managers concerned with the estuary and lower river. The estuary and lower river contain fish and wildlife resources of state, regional, and national importance, including major sport and commercial species such as coho and Chinook salmon, and endangered species such as the Columbian white-tailed deer. Further urban, suburban, industrial, and rural development on and near the river and estuary can conflict with these resources.

Of greatest public concern are the potential environmental impacts of energy related development. Studies that partially or completely center on the impacts of potential energy related development have been documented by Pruter and Alverson (1972), Morgan, Marston, and Holton (1979), Oceanographic Institute of Washington (1978a,b), Seaman (1977), and the CPCR.

The area chosen for this study encompasses the Columbia River Estuary Watershed Unit characterized in the CPCR and extending 50 miles up-river, to river mile 83 on the Washington side, and river mile 93 on the Oregon side. The additional 50 river miles were included due to the projection of extensive development with serious fish and wildlife consequences immediately up-river from the estuary.

ANALYSES AND CONCLUSIONS

Chapter 1 of this report is a User's Guide that gives access to information and explains the study approach and organization of material. The following summary proceeds sequentially through the nine chapters of the report, highlighting salient conclusions and analysis.

Scenarios in Chapter 2 project high, medium, and low probabilities for the development of energy related facilities (Table 2-1) at five, fifteen, and twenty-five year planning horizons (i.e., 1981-1986; 1987-1996; 1997-2006). Electric generating, fuel processing, transmission, transportation, extraction and associated support facilities are described. The scenarios are based on analysis of the major factors affecting energy consumption and demand for energy related facilities in the Columbia River Estuary.

Only a few current proposals for facility development are expected to be completed by 1986 (five year forecast). The 15 year forecast (1996) is the critical period for realization of projects now under serious consideration. Longer range forecasting is more speculative. Intensive energy related development of the Columbia River Estuary is not foreseen. The probability for development of certain types of facilities, however, is high, and a variety of potentially significant energy related environmental effects are anticipated. For example, numerous small hydroelectric projects may further jeopardize the Columbia River salmonids. Although small dams will be predominately low head, run-of-the-river plants, they may block tributary spawning beds from the last remaining natural-run salmonids in the Columbia River drainage.

No new large thermal power plants, nuclear or fossil-fuel, are likely to be constructed in the study area. The probability of construction of any new nuclear generation plant is slim throughout the Pacific Northwest, but if a plant is built in the study area, it would most likely be located at the Trojan Site. An expansion of the intermediate load Beaver generating plant, to incorporate additional gas fired units is highly probable. Coal gasification at the Beaver facility has been suggested by Portland General Electric (PGE), and is assigned a medium-to-high probability for the 1987 to 1996 period. No other significant synthetic fuel developments are projected for the study area, and no increase in nuclear or waste processing is expected.

By 1995, a small-to-medium sized, low complexity oil refinery may be sited at Dibble Point-Ranier, Deer Island, Port Westward, or Cottonwood Island. A medium probability exists that one facility will be constructed between 1987 and 1996, and low probabilities exist for a second and a third facility between 1997 and 2006. A reasonable probability exists that one marine terminal for receiving, storing, and regasifying liquefied natural gas (LNG) will be constructed in the Pacific Northwest, but much more attractive sites than the Columbia River Estuary are available. On the other hand, two or more liquefied petroleum gas (LPG) plants will probably be constructed at Columbia River ports by 2006, but would most likely locate upriver in the Vancouver/ Portland area, as the smaller vessel size makes accessible favored sites, closer to markets.

A variety of energy related upgrading of existing transportation, handling, storage, transshipment, and transmission facilities are forecast. Handling of coal, in particular, is likely to increase. New coal terminals at Kalama and Tongue Point are strong possibilities within 15 years. The Northwest Natural Gas pipeline will probably be expanded to accommodate increased production following discoveries at Mist, Oregon. Development of oil or gas fields, LNG/LPG facilities, or refineries would entail associated fuel pipeline development. Increased marine vessel traffic will be required in support of new terminals and for facilities that require fuel transshipment. Improvement of roads and railways may be required at some locations. No major new transmission corridors are forecast.

Onshore oil and gas exploration is being considered for the Wauna-Westport Slough area, but commercial production is uncertain, and the probability of exploration at other sites appears low. Little prospect for significant Outer Continental Shelf (OCS) oil and gas exploration and production offshore from the Columbia River Estuary is foreseen.

Chapter 3 summarizes the direct and indirect impacts of energy related development upon fish and wildlife in the estuarine environment. Secondary impacts due to increased growth fostered by energy development are not projected. Discussion is limited to those impacts associated with the facilities identified for probable development within the timeframes given in Chapter 2. Where possible, significant impacts are identified and directly related to specific estuarine processes; however, the lack of applied research in estuarine environments often restricted quantitative analysis.

The most significant impacts caused by energy related development in the Columbia River Estuary are likely to be those associated with cumulative losses of small increments of habitat, as well as the effects of chronic, low-level effluents and emissions on ecosystems. The activities which contribute the most pervasive or serious effects include landfill and construction in riparian areas and the estuary; dredging of channels for marine vessel traffic; construction of dams or pipelines directly in aquatic habitats; handling and spillage of fuels, especially coal and oil; fugitive emissions from coal and oil processing; thermal effluents from refineries, coal gasification, thermal power generation, and thermal effects of dams; location of small hydro projects in natural spawning beds in the tributaries of the lower river; and clearing and maintaining rights-of-way (ROW) for energy related corridors.

Chapter 4 depicts ecosystem modeling of energy related developments. Models are included for riverine, estuarine, channels, sandflat, mudflat, emergent vegetation, and riparian habitats. The riparian model is presented first without energy development, and then separately in combination with eight types of energy related developments in order to reflect the diversity of impacts on riparian habitats. The ecosystem models use the methodology developed for the CPCR, and portray interactions between physical processes, biological communities, and human activities.

The greatest impacts on the riverine ecosystem have been produced by existing main stem dams above the study area, which have altered flow regimes, increased water temperature, and reduced sediment load, all of which have affected aquatic organisms. Of great concern are the effects on fish, particularly those posed by barriers to migrating anadromous fish. Tributaries to the lower Columbia River and Estuary are particularly threatened by small hydroelectric development that may deplete spawning habitat and interfere with migration. Increased turbidity will accompany construction of dams or pipeline crossings, and can damage fish gill lamellae and reduce benthic fauna. Hydroelectric developments have their most serious impacts on the riverine environment and on anadromous fish. Process water used for fuel transportation (coal slurry) or for processing may become a serious source of pollutants. Dredging for marine navigation would sharply increase the release of contaminants into the water column.

The estuarine ecosystem is defined and zoned by the water salinity gradient. The Columbia River Estuary is not surrounded by industrial development or heavily populated uplands, but receives pollutants from upstream sources and traffic passing through to upstream points.

Estuarine sediments provide food, shelter, and substrate for diverse plant and animal life. Bacteria in the sediment decompose organic wastes and in the process recycle nutrients back into the estuarine system. Dredging and filling directly impact the channels and fill areas and also impact the water column through resuspension of fine materials and possible release of toxins from the sediments.

The combined primary production of estuarine wetlands, the benthos, the water column and import of organic materials from upriver and oceanic habitat support the food chain within the estuary. The marsh plants in the wetlands supply detritus, forming the base of the food chain, whereas the phytoplankton is directly grazed upon. It is not yet determined which source, water column phytoplankton or detritus, is the principal source of energy for animal protein production (Envirosphere 1981). Each source is important to a variety of species of concern at higher trophic levels. Freshwater diatoms are dominant in the Columbia River Estuary and reflect its salinity structure.

The invertebrate community of the Columbia River Estuary is a diverse assemblage of organisms occupying both the water column and the sediments. Some forms are strictly planktonic, occupying the water column for their entire life cycle. Others are epibenthic, occupying the water column at times for feeding or migrations and spending the rest of the time on or in the sediments. Those that are considered strictly benthic (bottom) dwellers often have planktonic larval stages.

The fish community of the Columbia River Estuary is composed of a variety of marine, anadromous, estuarine, and freshwater fishes which use the estuary for spawning, feeding, and migrating. The major species in the estuary are listed in Table 4-9.

Impoundments upstream have increased shoaling in the estuary, and maintenance dredging has been considerable. The estuary is vulnerable to trapping and suffering long-term contamination from toxic spills, such as oil; tidal action and river flow make containment difficult. Aquatic pipeline crossings or extraction activities may be sources of accidental contamination if ruptures occur, or containment is breached.

Terminals in estuarine and riverine habitat may create new piling habitat with piers and docks. The benthic community will be removed by dredging for navigation channels in this environment, and benthic succession and fish and wildlife use may be altered by a continuous use for energy related marine traffic and maintenance dredging. Diving birds (e.g., grebes, cormorants, scoters) may be affected by contamination from spills and chronic releases of pollutants. Channels have altered salinity and stratification characteristics, and sedimentation occurs differently in them. These are used by adult and some juvenile anadromous fish during migration.

A number of habitats or habitat types, and their descriptions, and a generic review of their response to energy development are given in this chapter. They are mudflats, sand flats, emergent vegetation and marshes, and riparian lands.

Chapter 5 provides brief species accounts of fish and wildlife inhabiting the Columbia River Estuary that have commercial or recreational value, or are of particular ecological significance. The accounts also indicate major environmental disturbances that may detrimentally affect the populations.

The annotated accounts include waterfowl and shorebirds, a small crustacean, chinook salmon, coho salmoon, steelhead trout, dungeness crab, great blue heron, western and glaucous gulls, and white-tailed deer.

Chapter 6 analyzes projected energy developments and their potential environmental conflicts. Proposed developments are fewer in number and kind within the estuary (below river mile 25) than in the lower Columbia River (upstream to river mile 93, the upper boundary for analysis).

Within the estuary study area, there are eight possible sites identified for OCS support, three sites for coal transshipment terminals, an existing 8,000 kW back-up fossil-fuel power plant (by Youngs Bay) which is no longer in use, and a small hydro power (17 MW) site which may be developed on a tributary (Grays River) to the estuary. Developments bordering the estuary are more likely to be in Oregon. Despite the number of sites identified, energy related developments within the estuary by 2006 probably will be limited to one coal terminal and a few OCS oil and gas support bases.

The most significant existing energy related developments are the main stem hydroelectric dams which have produced an increase in temperature, a decrease in flooding, an increase in estuarine sedimentation, and a partial blockage of fish passage in the estuary and lower river. Additionally, the maintenance dredging program of the U.S. Army Corps of Engineers has significant cumulative environmental impacts which are described in this chapter.

Chapter 7 provides generic, facility oriented measures for management and mitigation of environmental impacts due to the construction or operations of energy facilities projected for the Columbia River Estuary. No attempt is made to evaluate or endorse the best available mitigation measures.

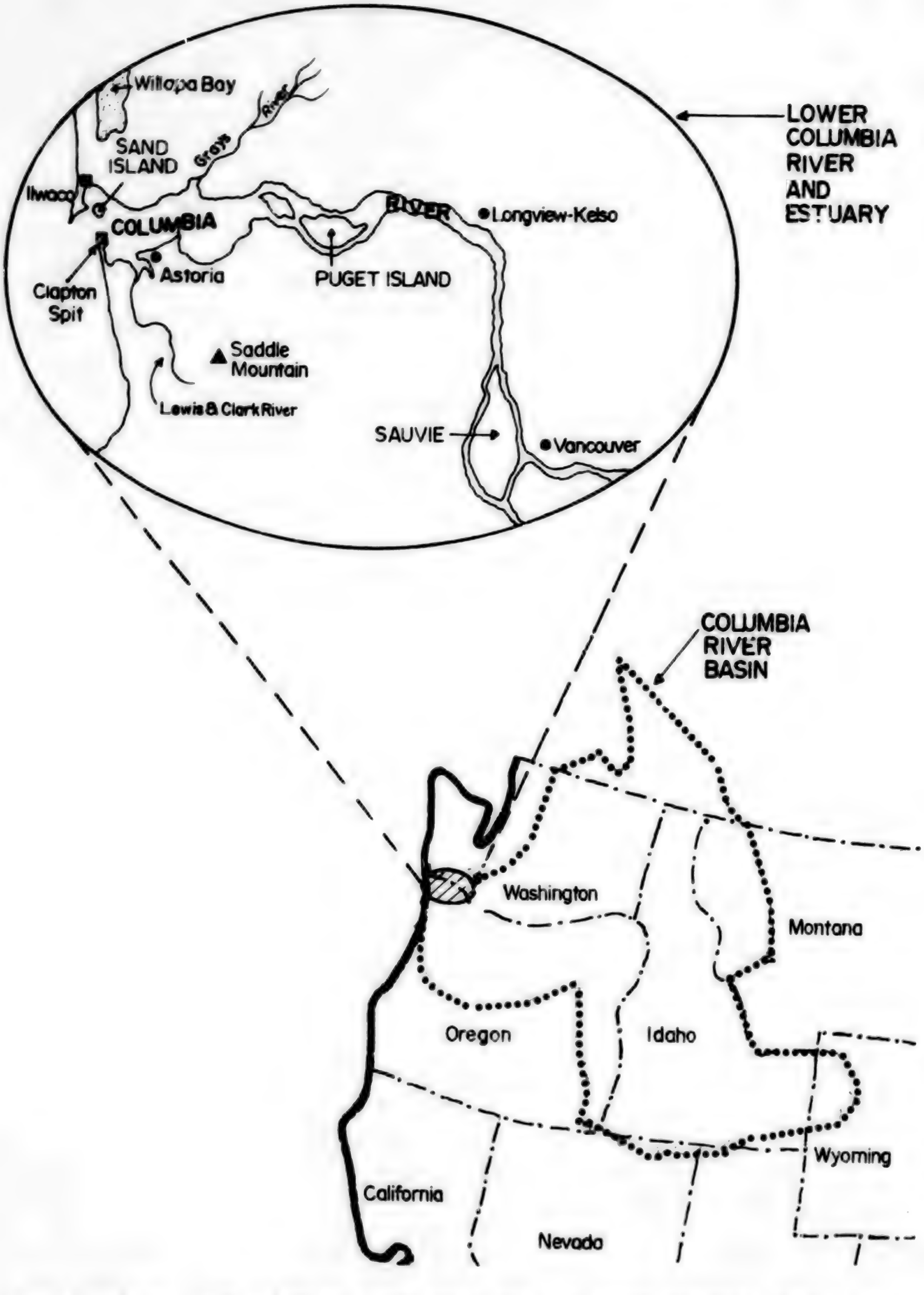
Chapter 8 discusses management and mitigation measures applicable to the most valuable fish and wildlife species. The array of mitigation actions is illustrative of the pool of measures available to ameliorate adverse impacts caused by energy related developments in the Columbia River Estuarine area.

Among the numerous practices generally applicable to protect, enhance, and compensate for losses incurred by these species are: maintenance of buffer zones around critical habitats; construction of subimpoundments to stabilize water fluctuations; construction of islands and artificial nest and roost structures; minimal use of persistent toxic substances; advantageous management of grazing and domestic livestock; and proper design, siting, operation, and maintenance of transmission lines, pipelines, and transportation corridors.

Chapter 9 reviews the policymaking, planning, and regulatory roles of the complex federal, state, regional, and local public and quasi-public bodies which implement and influence the decision making process for energy development. The opportunities for USFWS input to decision making are described, and the regulatory requirements applicable to each type of energy facility are outlined.

USFWS participation in the Columbia River Estuary Study Task Force/ Columbia River Estuary Data Development Program (CREST/CREDDP) and the planning activities of the new Pacific Northwest Electric Power and Conservation Planning Council is essential. Other planning processes in which USFWS should participate include county comprehensive planning, oil and gas leasing, regional transmission system planning, channel maintenance, dredge disposal, and economic development.

A number of general federal regulatory tools may benefit USFWS in attaining fish and wildlife goals for the Columbia River Estuary; examples include the National Environmental Policy Act (NEPA) and the Water Pollution Control and Clean Air Acts. Washington and Oregon's Shoreline Management Acts are also of importance. A review of the numerous regulatory requirements that apply to the various kinds of energy facilities is provided.



Frontisepiece. The Columbia River Basin and the Lower Columbia River and Estuary Study Area.

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CHAPTER 1.0 USER'S GUIDE

1.1 APPROACH TO THE STUDY AND ORGANIZATION OF MATERIAL

The investigation of the Columbia River Estuary energy related use conflicts centers on the projection of energy related development in the estuary. These projections (Volume I, Chapter 2.0 and Volume II) provide the foundation from which salient environmental impacts are derived (Chapter 3.0), site-specific conflicts are identified (Chapter 6.0), and cumulative impacts are defined (Chapter 6.0). Estuarine habitats are modeled (Chapter 4.0) and fish and wildlife species of concern are reviewed (Chapter 5.0) interactively with projected development, to disclose conflicts with forcasted energy related growth. Management and mitigation of impacts and conflicts are addressed on three levels: facility-specific management and mitigation (Chapter 7.0), species-specific management and mitigation (Chapter 8.0), and human-system policy, planning, and regulatory processes (Chapter 9.0). Figure 1.1 shows the interrelationship of study sections.

The forecasts of energy related development (Volume II) are based on an analysis of the Columbia River Estuary within a regional context. This forecast relied on existing ones prepared by the Bonneville Power Administration (BPA), Northwest Energy Policy Project (NEPP), Pacific Northwest Utilities Conference Committee (PNUCC), Natural Resources Defense Council (NRDC), and other groups, all of which are regional in scope. Given the identified regional demand for energy in various forms, analysts attempted to assess the probability that given types of facilities designed to meet that demand would be sited in the Columbia River Estuary.

Estuary values were weighed against values of alternative available siting options to arrive at relatively qualitative judgements regarding the attractiveness of locating new facilities there. These judgements relied on: interviews and contacts with government agencies, utilities, energy companies, ports, and other development interests; the stated plans of these groups in published documents; siting suitability studies by federal and state agencies for particular types of facilities (e.g., small hydro sites); and local government Coastal Zone Management or Shoreline Management plans and programs, comprehensive plans, and zoning ordinances.

Based on the foregoing analyses, facilities were assigned sites, levels of probability, and timeframes. Sites where development may occur are identified for each level of development probability (low, medium, high) and each timeframe assessed (1981-1986, 1987-1996, 1997-2006). These forecasts are coded, and symbols representing the various types of facilities are mapped for each scenario.

The maps, presented in the Atlas (Volume II) accompanying this report, combine the three levels of probability and the three timeframes to yield

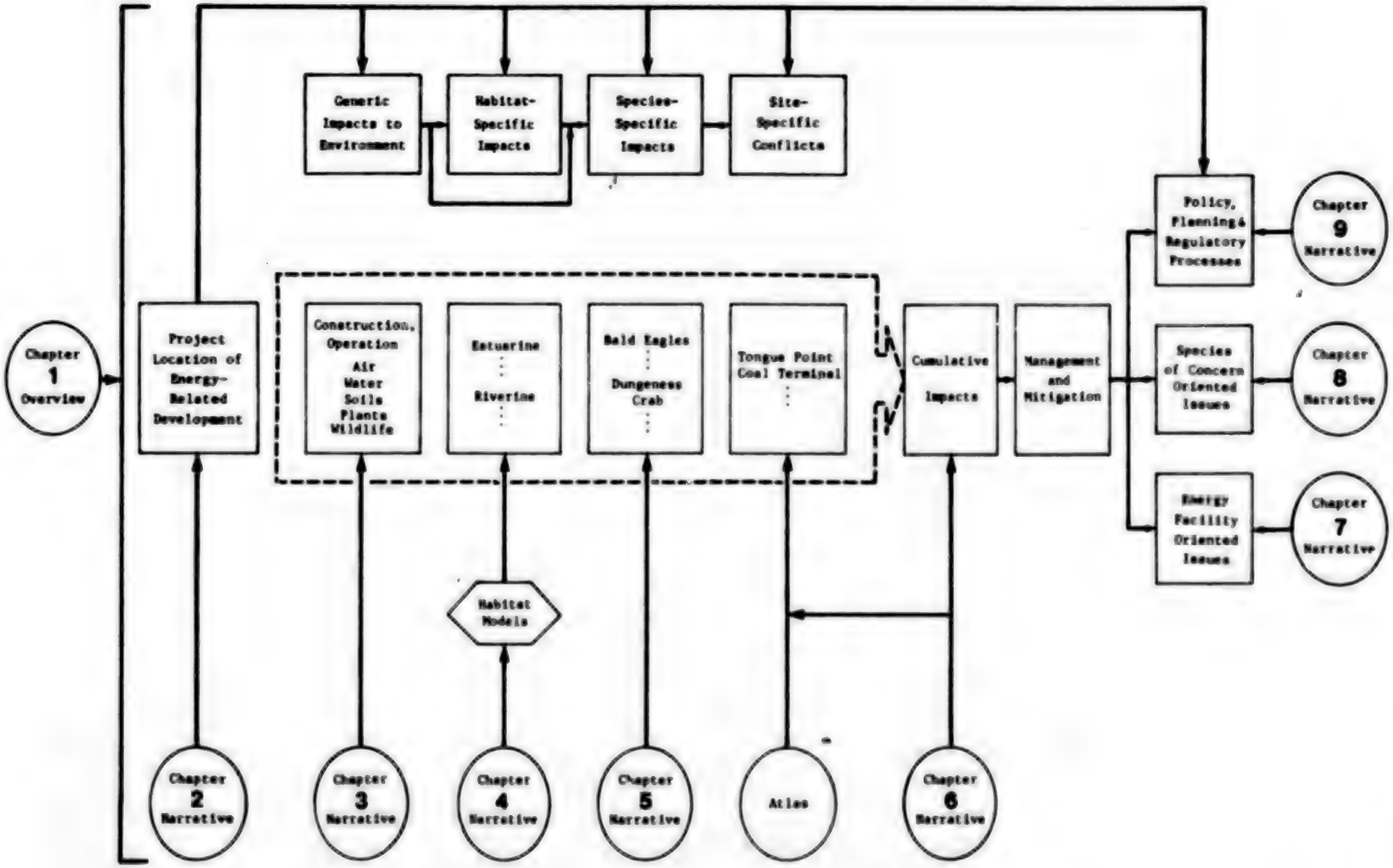

Figure 1.1. Flow diagram of the chapters and their interrelationship in the Columbia River Estuary.

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nine projections which aggregate successively higher probabilities and longer periods. Existing energy facilities are also briefly reviewed in Chapter 2.0 and are shown on the scenario maps in Volume II. Overview maps at 1:250,000 have been prepared for each of the three levels of probability for the entire Columbia River Estuary study area. These maps aggregate all facilities projected for 1981 to 1986, 1987 to 1996, and 1997 to 2006. Detailed mapping of each probability level at each timeframe occurs on eleven USGS 15' quads. An overview map keys the user to the appropriate quad for review of development in each portion of the estuary.

Following the same outline of energy related facilities established in Chapter 2.0, a summary review of literature on fish and wildlife impacts is presented in Chapter 3.0. The discussions are generic, describing the kinds of environmental effects ascribable to various types of energy developments and relating them to estuarine processes and species. The impact summary relied on the literature regarding environmental impacts of energy systems, extrapolating it to the estuarine and closely related ecosystems in instances where material applicable to those environments was unavailable.

Chapter 4.0 takes a further step, providing ecosystem models for the six major habitats found in the Columbia River Estuary study area. The models incorporate the generic types of impacts identified in Chapter 3.0 associated with the various energy developments projected in Chapter 2.0, as ecosystem inputs. The facility related impacts are summarized and translated into habitat-specific terms in a series of tables (Tables 4-1 through 4-7) prefacing the models. The modeling methodology used was developed and described in detail in Volume 1 of the Ecological Characterization of the Pacific Northwest Coastal Region (CPCR).

A model is a symbolic representation of a part of the real world, such as an ecosystem. The symbols used may be verbal and graphic, as in a conceptual model such as these, or they may be mathematical as in a model used for simulation and quantitative prediction. The purpose of a model is to simplify a complex array of interrelationships into a manageable framework while maintaining the integrity of the system.

It must be recognized, however, that models are only simplified representations of reality. Anyone who has used ecosystem models will recognize that, at best, they are gross pictures of selected features of a system and the relationships among them. As such, ecosystem models can be useful tools in approaching a system and beginning to study and understand it. At worst, models can be misleading, giving a sense of understanding which, in reality, may be superficial or misdirected. The adequacy of models is largely based on the needs and knowledge of its users. These models are intended to be of general assistance in management decisions by a combination of technical and nontechnical persons. Many relationships are generalized, but provide a basis from which treatment of specific factors is possible.

Chapter 5.0 focuses on energy related impacts on species considered ecologically significant by the U.S. Fish and Wildlife Service (USFWS). Species were selected for in-depth review because of their commercial or recreational value, endangered status, or importance as food sources within estuarine food chains. The accounts rely on the scientific literature to summarize the species' ecological requirements, resource value, population status and trend, estuary use, and factors affecting their distribution and abundance.

Chapter 6.0 integrates the material developed in Chapters 2.0 through 5.0, to provide a comprehensive treatment of site-specific conflicts and cumulative impacts. The site-specific impact presentation uses the energy development projections and mapping to identify conflict sites, specific impact issues at each site, and habitat and species of concern affected. Areas and species of concern are identified based on both the foregoing analysis and supplementary reference to compilations of other researchers. As a final integrative step, cumulative impacts are summarized.

Management and mitigation options are discussed in the final three chapters of the report, from three perspectives: facility-oriented options, species oriented options, and human-system planning, policy, and regulatory processes. Both Chapter 7.0, facility oriented measures, and Chapter 8.0, species-specific measures, were prepared from a broad review of the literature. These chapters do not purport to evaluate or recommend best available management and mitigation measures and should be used as guides to the kinds of issues and approaches available. Chapter 9.0 compiles information on the wide variety of public or quasi-public bodies and processes which define policy, plan, or regulate elements of the environment or energy development. This information will influence fish and wildlife management options.

1.2 ACCESS TO INFORMATION

The user will be best prepared to appreciate the utility and significance of the material organized in this report by first scanning Chapter 2.0, Energy Development Projections, and Volume II.

Energy facilities are grouped into four major sectors -- electric generating, fuel processing, transportation and transmission, and extraction facilities. Each category contains a background subsection which briefly describes the types and most important features of the facilities included in the category and outlines the regional setting in terms of demand for the facilities, use of the energy they produce, Pacific Northwest sources of supply, and present forecasts for growth in that sector.

A potential development subsection follows, which provides the forecast of number, location, and other parameters for each type of facility. In this subsection, a probability matrix summarizes the forecast narrative for each type of energy facility, showing the probability of development in each time frame.

To seek information on a particular type of development, the user should find the appropriate mapping code for that facility in the legend presented in the Atlas for locating site(s), timing, and probability. For narrative, the user should refer to the generic category in which the facility is included, and find the numbered subsection most closely corresponding to the specific facility in question. If no information is presented, that type of facility is not projected to be developed. Unconventional facilities, including all renewables except hydro are not forecasted in this document.

Chapter 3.0, Literature Review of Energy Related Impacts to Fish and Wildlife in Estuarine Systems, contains generic information about the environmental impacts of the energy facilities described in Chapter 2.0. Generally, the user will find that impact information is arranged following the same facility outline used in Chapter 2.0. However, during the construction phase most energy facilities share a somewhat homogenous set of impacts, typically associated with large construction projects. These impacts vary more according to the nature of the habitat in which construction occurs than by the kind of facility under construction. Section 3.2 describes environmental impacts of construction in terrestrial habitats, in aquatic habitats, and in corridors which cross both types of habitats.

For each impact discussion, whether of construction in a particular habitat, or of operation of a particular kind of facility, the user will find three types of information. First, a summary subsection very briefly reviews the types of facilities and the probabilities of their development in the Columbia River Estuary. Next, the discussion of their significant estuarine impacts is presented. Finally, a short ecosystem perspective on impacts reviews the nature and mechanism of the impact in terms of the ecosystem structure and function.

In the analysis of land based construction phase impacts (terrestrial habitats and corridors), the environmental effects are organized under the general heading, Significant Estuarine Impacts, according to the elements of the environment affected (air, water, land, soil and sediments, vegetation, and fish and wildlife). For the aquatic habitat construction phase and all operation phase analyses, the user will find environmental impact discussions under this general heading organized according to specific impact issues. For example, impacts of transmission lines are characterized under the subheads avian collisions (waterfowl and shorebirds), electric line effects (electric fields and raptor electrocutions), and maintenance of towers and right-of-ways (ROW's) (clearing, herbicides).

Chapter 4.0, Ecosystem Modeling of Energy Related Development, incorporates environmental impact inputs associated with the various kinds of energy facilities within ecosystem models for the six major habitats found in the Columbia River Estuary study area. The models are arranged uniformly so that within an ecosystem, the physical processes are presented on the left side, biological processes in the middle, and socioeconomic activities on the right (see Figure 4.1). Natural inputs and outputs to the ecosystem interface from the left, and socioeconomic inputs and outputs interface mostly from the right. The symbols used are mostly based on Odum (1971 and 1972); the Glossary of Symbols from the CPCR is also reproduced in Chapter 4.0.

The user may easily translate the generic impact discussion of Chapter 3.0 to the ecosystem model impact inputs by using the seven habitat-specific impact tables, provided for each type of energy facility, which appear at the front of Chapter 4.0.

A complex general ecosystem model is given, and each of the ecosystem models are graphically presented, showing inputs, processes, major components, and flows. These model elements are numbered, and numerically keyed narratives accompany the graphic presentation, expanding on the role, composition, and significance of each element. Each model discussion concludes with a review of hazards associated with energy facilities, treated as ecosystem risks. The discussions of generic impacts in Chapter 3.0 should be consulted by the reader in relation to review of the impact inputs to the models presented in Chapter 4.0. Each ecosystem model may be used as a comprehensive framework within which the path of a given energy related impact can be traced, allowing identification of environmental elements and processes at risk. The models may be used interactively to understand how development in a given habitat may influence adjacent habitats.

Chapter 5.0, Species of Concern, focuses the user on selected fish and wildlife which are valued for commercial or sport harvest, are endangered, and/or play an important ecological role in community structure and function. Each species or species group is discussed using the same format. After a brief introduction and description of the organism or group, the resource value which justifies the species of concern status is identified, and the use of the estuary by the species is characterized. The following subsection outline population status and trends, life history, food habits, and factors affecting distribution and abundance. The user should relate the habitat models described in Chapter 4.0 to data on estuary use, life history, and food habits contained in the species account in order to gain a full appreciation of the effects at the species level of energy related habitat impacts.

Both human and natural factors which affect species distribution and abundance are presented. The user should relate these descriptions to material on energy related impacts presented in Chapter 3.0 to understand the kinds and potential importance of effects attributable to an energy related development.

In Chapter 6.0, the user will find an integrated analysis and tabular presentation of energy related use conflicts on a site-specific basis. Table 6-2 is organized by river mile, proceeding from the mouth of the Columbia River up to Portland (river mile 102), and organizes information on a site-by-site basis regarding location, state (side of the river), type of facility, probability level in each time frame, projected impact characteristics within estuarine, riverine, and riparian habitats, areas of concern, species of concern, and related comments. If development in a particular river reach concerns a fish and wildlife manager, this table should be consulted first, starting at the point of concern and proceeding up and downstream to identify specific potential energy related developments which may impact the species or habitat in question. A summary table (6-1) will help quickly locate projected energy developments by river mile. Following the site-specific impact assessment, the user will find a discussion of the cumulative energy related environmental effects of most significance.

Chapter 7.0, Generic Energy Facility Oriented Management and Mitigation, follows much the same outline of impacts and division of construction and operation phase measures as Chapter 3.0. Because management and mitigation can begin with design phase avoidance of problems, the discussion opens with a consideration of issues relating to facility siting. Construction phase impact management and mitigation is again grouped and analyzed by type of habitat, first for projects in terrestrial habitats and next for those sited in aquatic habitats. Operation phase management and mitigation is first discussed in terms of certain impacts which are common to many types of energy related facilities (oil spills, thermal effluents, dredging) and finally on a facility-by-facility basis for ten types of energy related developments that may confront fish and wildlife managers in the Columbia River Estuary in the next 25 years.

Chapter 8.0, Fish, Wildlife, and Habitat Oriented Management and Mitigation, continues the generic description of measures available to protect fish, wildlife, and their habitat, from a species oriented perspective. The measures provided in both Chapters 7.0 and 8.0 are not site-specific, and do not attempt to specify techniques in detail or present recommendations. They illustrate the range of issues and approaches. Chapter 8.0 provides a tabular partial list (Table 8-1) of state agencies which regulate aspects of fish, wildlife, and their habitats, and the permits required for certain activities. The management and mitigation guidelines and options which are given for eight species or species groups anticipate indirect secondary and tertiary impacts to which fish and wildlife managers must respond. The user may relate energy facilities identified in Chapter 2.0 and impacts characterized in Chapters 3.0 through 6.0 to the management and mitigation measures specified in Chapters 7.0 and 8.0 by correlating either the type of energy facility in question or the species of concern.

Chapter 9.0, Planning, Policy, and Regulatory Processes, completes the human-environmental system analysis by linking environmental, fish, and wildlife concerns with the human decision processes which affect and control them. The user should refer to this chapter in developing a long-range strategy to build a management plan to protect fish and wildlife values. The chapter provides information on "who is involved" and "how they work" for three classes of human action: policy-setting, planning, and regulation. Policy and legislation are described at the federal, state and local levels. Planning processes are particularly emphasized for local comprehensive and coastal management programs, but also cover state, regional, and federal entities. Regulatory processes are described by facility type.

1.3 INTERFACE WITH RELATED DOCUMENTS

This investigation may be usefully related to complementary Office of Biological Services documents, for full appreciation of fish and wildlife issues, ecosystem models, and environmental impact significance. The Pacific Coast Ecological Inventory should be consulted to provide a regional context for this analysis. The CPCR provides comparative ecosystem models, including a characterization of the Columbia Estuary Watershed Unit. The CPCR also provides in-depth discussion on ecosystem modeling, zone and habitat descriptions, and data source access. These may be used for access by habitat, area, species, subject, or human activity, to integrate data between the two reports.

Habitat food webs presented in the An Ecological Characterization of the Pacific Northwest Coastal Region (CPCR) Vol. 3, provide better definition of the biological community composition than the ecosystem models, but are generalized for habitat types and may still vary between locations within the Columbia River or its estuary. For a specific site, the habitat models in Chapter 4.0, the habitat food webs in the CPCR, and the community composition combined, may help to distinguish the biological aspects of a site important to a species.

The Columbia River Estuary Data Development Program (CREDDP) research data will help to identify important food species for other species of concern. It is unlikely that it will define the significant differences of pollutant uptake, bioaccumulation, and food chain magnification affecting species of concern for discharges and spills of the wide range of materials associated with energy facilities.

The conceptual modeling does not address behavioral aspects of fish and wildlife in respect to energy developments. The CREDDP biophysical interactions group was working with Hypothesis Systems Models (HSM's) which emphasized behavioral aspects of some species of concern (such as salmon). Preliminary ecosystem modeling for CREDDP used modified Forester symbols, which are considerably different from the modified Odum symbols used in this report and in the CPCR.

The Nature Conservancy's Natural Heritage Program may be consulted in Washington or Oregon for additional detail on species of concern, and state fish or game agencies may also be consulted on a project- or species-specific basis for further detail.

CHAPTER 2.0 ENERGY DEVELOPMENT PROJECTIONS

2.1 METHODS

2.1.1 Objectives

The purpose of this task is to assess potential energy related development within, or directly affecting, the Columbia River Estuary Study Area; to identify sites where such development is likely to occur; and to map this information in terms of a set of scenarios of projected development. These scenarios are given in Volume II. The assessment and projections provide a basis for modeling and evaluating impacts of energy related facilities and activities on wildlife species and habitats, leading to development of management and mitigation procedures.

The types of facilities considered in assessing the potential for energy related developments are presented in Table 2-1. Potential locations for the placement of energy related facilities were identified based on: 1) stated plans or actions of utilities, energy companies, port districts, and other development interests, and coinciding actions of federal and state regulatory or land management agencies; 2) studies of potential and/or suitable sites conducted by federal agencies such as the U.S. Army Corps of Engineers, state energy facility siting councils, and other state agencies concerned with economic development, transportation, and land use planning; and 3) local government Coastal Zone Management or Shoreline Management plans and programs, comprehensive plans, and zoning ordinances.

Potential locations and focal points for secondary development including industrial and transportation support facilities, and secondary urban growth that are direct results of energy facility development are also identified.

The above information is synthesized into maps of generalized, site-specific development projections in which potential energy related development sites are identified by type and delineated for three time increments (1981-1986, 1987-1996, 1997-2006), for each of three scenarios based on low, intermediate, and high energy related growth. These maps make up the Atlas (Volume II).

2.1.2 Study Area

For purposes of this task, an area larger than the project study area was considered, to allow for possible impacts of energy facilities developed in surrounding areas, particularly sections of the Columbia River and its tributaries immediately upstream of the estuary study area. The

Table 2-1. Energy related facilities in the Columbia River Estuary area in 1981.

Facilities	Categories
Electric generating	Hydroelectric Thermal-electric Fossil-fuel (coal, oil, gas, combined cycle) Nuclear
Processing	Liquid natural gas (LNG)/Liquid petroleum gas (LPG) Refining Synfuels - coal gasification Conversion Biomass conversion Uranium
Transportation	Coal (rail, marine terminals, shipping) LNG/LPG (shipping, marine terminals, pipelines) Oil (shipping, marine terminals, pipelines) Natural gas pipelines Electric power transmission lines
Extraction	Oil wells Gas wells
Support	Secondary industrial/transportation

its tributaries immediately upstream of the estuary study area. The territory surveyed included all of the Columbia River drainage in Clatsop and Columbia Counties in Oregon, and in Pacific, Wahkiakum, and Cowlitz Counties in Washington, and to approximately river mile 83 for the Washington side (mouth of Lewis River) and river mile 93 for the Oregon side (Sauvie Island). Some ongoing and proposed development activities in Multnomah County (Portland) and in the mid-Columbia region are noted, mainly as they relate functionally or competitively to energy development in the primary survey area.

2.1.3 Data Collection

Two major sources of information were used during this study: agency contacts/interviews and documentary data. The selection of interview contacts emphasized key agencies and organizations, plus a representative sample of others. A balance between the regulatory and developmental aspects of energy supply was sought, and both operational and policy-making/planning perspectives were solicited.

2.1.4 Data Synthesis/Mapping

An initial level of data synthesis occurs for each of the types of energy facilities listed in Table 2-1. In the following sections of the report, an assessment is made of the probable extent and locations of development of each category of facilities, broken down by its constituent subcategories for three time periods: 1981 to 1986, 1987 to 1996, and 1997 to 2006.

The assessment is based on the following background information: current conditions, forecasts of energy use, trends in energy development as related to both category and region, and existing facilities within the study area. Federal, state, and local government policies and actions that encourage or constrain development were evaluated; however, the subject of governmental regulation is not treated at length within each section. Section 9.2 provides a summary of regulatory functions of each level of government for all the categories of energy facilities. This information is then combined with information about specific development proposals for each category and the estimated lead time for approval and construction. This provides the basis for the 1981 to 1886 and the 1987 to 1996 period assessments.

Only a few current proposals for facilities development are expected to be completed in five years. The second time increment is the critical period for realization of most of the projects now under consideration. The assessment for the 1997 to 2006 period is less tied to specific present development proposals, relying more heavily on applicable long-range forecasts, and on basic site availability information (e.g., Norris Study, U.S. Army Corps of Engineers National Hydroelectric Power Study, Corps Maintenance Disposal Plan). The location of each identified project is indicated on a Site Reference Map, prepared at a scale of 1:250,000 (see scenario maps in Volume II). Existing energy facilities are also shown on this map.

The result is a set of potential energy facility developments for each category given in Table 2-1, identified as to sites, and with a qualitative probability of development (high, medium, low) assigned for each of the three time increments. The probability assigned to each prospective development attempts to take into account the total set of market-economic and institutional factors, as well as the competing site opportunities for that type of facility.

In many cases, site opportunities are well defined by physical factors, ownership, and/or transportation access. However, the existence of a suitable site for a particular facility does not resolve indeterminacy related to whether the Columbia River study area will, as a whole, be preferred over some other area. Institutional constraints can often be assessed with some certainty, because government at all levels has been formulating clearer policies and procedures for energy facilities development, siting, and regulation. In addition, legal descriptions of areas stipulated for development are available; for example, see planning designations and conditions for development at Tongue Point, the Port of Astoria piers, the East and West Skipanon Peninsulas, and Tansey Point (CREST Mediation Panel Agreements, July 1981).

The market-economic factors reflect the greatest indeterminacy, because of their dependence on highly complex and variable sets of circumstances. Many of these are exogenous to the study area and the Pacific Northwest. Indeterminacy also exists where different forms of energy are competing, and future competitive advantages of one type or another are difficult to predict.

The final synthesis of these assessments for each type of facility is expressed in the composite scenarios of projected development mapped on a USGS 1:62,500 base, with annotation related to specific sites and projects (see Volume II). This is basically an additive process. Developments of like probability assignment and time increment are combined serially with developments of the next higher probability and/or nearer time increment to produce three scenarios of cumulative development for the three time increments.

The weakness in this approach is that it does not take into account the interrelationships between different categories of energy development or the competition between different categories for markets and sites. Therefore, this additive synthesis must be modified to some extent, to at least make the scenarios consistent in terms of obvious interrelationships, for example between energy transportation and energy facilities at the origin and/or destination of transportation routes. Also, alternative types of development are possible for specific sites and are noted in the map. However, the development of a fully integrated set of projections of all energy facilities was beyond the scope of this study.

2.2 ELECTRIC GENERATING FACILITIES

2.2.1 Background

2.2.1.1 Current generation and consumption in the Pacific Northwest. Unlike other energy sectors that depend on fuels imported from outside the region (e.g., transportation), over 90 percent of the electric energy consumed in 1975 was generated by hydroelectric facilities within the three Northwest states or adjacent portions of the Columbia River basin (PNRC-NEPP 1978).

Hydroelectricity has been the most abundant energy resource in the Pacific Northwest. Its potential for future development is limited, though not insignificant. Additional peak capacity is available at many existing sites, and total undeveloped hydro potential, mostly at small sites, is theoretically substantial. However, it is generally accepted that future major additions to firm electric generating capability, at least in terms of large projects, must rely on thermal-electric generation processes.

Construction of several large thermal-electric installations is now underway to meet the major part of projected growth in energy demand. These large coal and nuclear plants are planned and scaled to meet regional needs and are developed cooperatively by the region's utilities. None are in the Columbia River study area; the nearest are two nuclear plants under construction at Satsop, 50 miles north. One of these plants, constructed by the Washington Public Power Supply System (WPPSS), has been mothballed, due to financial problems. No new projects of this type could be completed until after 1990, as the lead time for this type of facility is more than ten years. None are currently proposed for the study area.

Factors influencing the type and siting of energy facilities and the timing of investment are extremely complex in the Pacific Northwest; a regional analysis would only obscure the focus of this document on the Columbia River Estuary. Two factors of direct significance to the possible siting of energy facilities in the study area deserve note and are discussed in the following paragraphs.

The BPA, as marketing agent for the electric power produced at federal dams on the Columbia River system, has for several reasons been forced to issue "Notices of Insufficiency" to its preference customers (public utilities) and has allowed private utility and direct service industry power contracts to expire without renewal. The heavy dependence of small Northwest public utilities on BPA-marketed federal power, coupled with a possible deficit in that resource relative to anticipated utility loads and a possible reallocation of shares due to recent legislation and court actions has caused increased interest on the part of public utilities and cooperatives in developing their own localized generating capability. Such a trend is likely to be encouraged by BPA in its new role. Evidence of this trend is seen in the lower Columbia River area on the part of Public Utility Districts (PUD) in Wahkiakum and Cowlitz Counties, which have proposed their own small hydro-electric developments.

In response to the foregoing situation, recent passage of the Pacific Northwest Electric Power Planning and Conservation Act by the 96th Congress will greatly influence traditional relationships within the electric industry, particularly in the aquisition of new resources. For the purposes of this document it is important to note the priority the bill places on aquisition of conservation (first), renewable resources (second), and cogenerated power (third), before conventional thermal electric resources are tapped. These priorities may increase the probability that the study area will host at least some small share of regional resource development, in the form of smaller, more dispersed generating plants which make up the renewable resource and cogeneration categories.

2.2.1.2 Forecasts of energy demand. Electric demand forecasting is highly controversial in the Pacific Northwest because of wide variation in estimates of baseline inputs to forecast models (e.g., fuel price elasticity, conservation potential, etc.) and because of the enormous investment at stake. It is not within the scope of this document to review the nature and substance of this controversy, or the technicalities of forecast modeling.

Two forecasting efforts are briefly reviewed here. The first is a set of forecasts of total energy demand by sector (Table 2-2), developed by the NEPP and sponsored by the Pacific Northwest Regional Commission. The work was published in 1977, using a base year of 1974. NEPP developed these forecasts for three energy growth scenarios, low, medium, and high, based on sets of assumptions about future economic, demographic, environmental, and energy related variables.

Total energy consumption in the Pacific Northwest was forecasted to grow between 1974 and 2000 at compounded annual rates of 0.90 percent per year under the low growth scenario and 4.56 percent under the high growth scenario (see Table 2-2). The low (1.43 percent) and high growth rates (4.38 percent) for electricity alone fall within this range, with a figure of 2.62 percent for the medium growth scenerio.

Table 2-2. Projected annual percentage increase in energy consumption in the Pacific Northwest from 1974 to 2000.

		Projections		
Type of energy	Historical (1964-1974)	Low growth	Moderate growth	High growth
Electricity	5.94	1.43	2.93	4.38
Natural Gas	5.23	0.61	1.66	2.74
Oil	2.72	0.50	2.44	5.00
Coal	----	4.01	9.18	10.84
Wood	----	1.48	2.63	2.20
Total PNW	3.88[a]	90	2.62	4.56

[a] Excludes coal and wood.

The Pacific Northwest's publicly and cooperatively owned utilities, investor-owned utilities, Bonneville Power Administration, and the U.S. Army Corps of Engineers have historically cooperated in informal, long-range planning with respect to future regional power requirements. The West Group Forecast, a product of regional cooperation, is prepared annually by the PNUCC to show estimates loads and capabilities of resources for the West Group Area. This area includes all of Washington, the Idaho panhandle, Oregon, except for its southeast corner, and small portions of northern California, southern Idaho, and western Montana.

The PNUCC forecast consists of two load estimates for each future Power Year: the January peak load and the average load experienced over the course of the year, both expressed in megawatts (MW) (see Table 2-3). Load estimates are projected for each Power Year from 1980-81 through 1999-2000. The 1979 forecast showed a gradually declining growth rate, with peak loads growing at about 4.0 percent per year, but dropping to 3.3 percent by the end of the century, for an average of about 3.6 percent. The growth rate for average loads was lower, averaging about 3.4 percent. Power Years 2004-05 through 2019-20 were projected at a 3.02 percent compound rate of growth.

A summer supplement to the March 1980 forecast for power years 1980-1991, now forecasts a yearly average peak growth of 3.3 percent for the decade, and an annual load growth of 3.1 percent (PNUCC 1980). These growth rates are over one percent lower than the 1980-81 projected growth rate of 4.4 percent forcasted in 1977, and more than two percent lower than the 5.4 percent growth rate forecasted for 1980-81 in 1970. The PNUCC forecasts have for several years tended to increasingly overforecast demand growth (Washington State Senate 1981). These facts illustrate that although forecasts are changing in response to actual, observed changes in demand, they tend to lag.

The meaning of these forecasts in terms of impetus for new development proposals depends on a comparison of estimated loads and resources over the next 20 to 25 years, and resultant surpluses or deficits for each year. Such a comparison is shown in Table 2-4, which lists the current PNUCC load estimates for future power years and summarizes available resources to meet that demand, including both existing generation capacity and scheduled additions to capacity.

Although deficits are predicted for every year, there is no discernible trend until 1989. The deficits rise or fall (in one case almost to zero) as new projects come on line. Beyond 1989 there is a steady rise in the deficits because no projects are currently approved that would be completed in that time period, whereas load estimates continue to rise.

2.2.2 Existing Facilities

2.2.2.1 Hydroelectric. Hydroelectric generating facilities (Table 2-5) presently exist on only two tributaries of the lower Columbia River (below the confluence with the Willamette River), the Cowlitz and Lewis rivers, both in Washington.

Table 2-3. Load estimates (megawatts) for the future West Group Area electric loads.

Power year	January peak[a]	Average load[a]
1980-1981	27,341	17,490
1981-1982	28,459	18,167
1982-1983	29,771	18,942
1983-1984	31,027	19,853
1984-1985	32,168	20,508
1985-1986	33,266	21,156
1986-1987	34,325	21,786
1987-1988	35,504	22,424
1988-1989	36,668	23,121
1989-1990	37,928	23,837
1990-1991	39,156	24,565
1991-1992	40,354	25,290
1992-1993	41,652	26,043
1993-1994	42,966	26,814
1994-1995	44,222	27,600
1995-1996	45,734	28,409
1996-1997	47,199	29,249
1997-1998	48,727	30,133
1998-1999	50,350	31,056
1999-2000	52,050	32,030
2004-1005[b]	60,399	37,168
2009-2010	70,087	43,130
2014-2015	81,329	50,048
2019-2020	94,374	58,076

[a] Based on preliminary long-range projection of power loads and resources for thermal planning, West Group Area, 1980-81 through 1999-2000.

[b] Power years 2004-2005 through 2019-2020 projected at 3.02% compound rate of growth.

Table 2-4. Projected peak and average loads (megawatts) of electric power sources in the West Group Area of the Northwest power pool at 5-year intervals (1980-81 to 1999-2000).[a]

	1980-1981		1985-1986		1990-1991		1995-1996		1999-2000	
	Peak	Avg	Peak	Avg	Peak	Avg	Peak	Avg	Peak	Avg
Loads										
System loads	27,341	17,491	33,265	21,156	39,157	24,566	45,732	28,410	52,050	32,030
Exports	2,153	666	1,565	207	106	174	106	174	29	109
Total loads	29,494	18,157	34,830	21,363	39,263	24,740	45,838	28,584	52,079	32,139
Power resources										
Main hydro	28,925	11,540	30,262	11,566	30,440	11,550	30,440	11,550	30,440	11,550
Independent hydro	659	434	663	443	663	443	663	443	663	443
Total hydro	29,584	11,974	30,925	12,009	31,103	11,993	31,103	11,993	31,103	11,993
Ex. Sm. Thrm. & Misc.	209	56	251	89	251	89	251	89	251	89
Comb. turbines	1,287	355	1,466	369	1,466	369	1,466	369	1,466	369
Imports	1,415	1,425	1,160	1,214	720	532	240	288	240	198
Hanford	0	515	0	0	0	0	0	0	0	0
Centralia	1,313	882	1,313	854	1,313	897	1,313	918	1,313	918
Trojan	1,080	765	1,080	765	1,080	765	1,080	765	1,080	765
Colstrip 1 & 2	330	248	330	248	330	247	330	248	330	248
Boardman	477	191	477	358	477	358	477	358	477	358
WNP 2	0	0	1,100	825	1,100	825	1,100	825	1,100	825
Colstrip 3 & 4	0	0	980	711	980	735	980	735	980	736
WNP 1	0	0	1,250	869	1,250	938	1,250	938	1,250	938
WNP 3	0	0	1,240	620	1,240	930	1,240	930	1,240	930
WNP 4	0	0	1,220	366	1,250	938	1,250	938	1,250	938
WNP 5	0	0	0	0	1,240	930	1,240	930	1,240	930
Skagit 1	0	0	0	0	1,288	773	1,288	966	1,288	966
Pebble Springs 1	0	0	0	0	0	0	1,260	945	1,260	945
Skagit 2	0	0	0	0	0	0	1,288	966	1,288	966
Pebble Springs 2	0	0	0	0	0	0	1,260	945	1,260	945
Total resources	35,695	16,411	42,792	19,297	45,088	21,319	48,416	24,146	48,416	24,056
Hydro, sm. thrm. & misc. res	-1,554	0	-1,632	0	-1,641	0	-1,641	0	-1,641	0
Large thermal res.	-480	0	-1,349	0	-1,732	0	-2,303	0	-2,303	0
Planning reserve	-706	0	-2,123	0	-3,824	0	-4,451	0	-5,548	0
Load growth reserves	-541	-301	-551	301	-634	-334	-751	-393	-918	-488
Thermal realization adj.	0	48	0	-84	0	-287	0	-535	0	-487
Sus. pkng. adjustment	-3,979	0	-2,563	0	-2,582	0	-2,582	0	-2,582	0
Hydro maintenance	0	-21	0	-19	0	-19	0	-51	0	-51
BPA NW-SW intertie losses	-84	-20	-50	0	0	0	0	0	0	0
Net resources	28,315	16,117	34,524	18,893	34,675	20,679	36,668	23,167	35,424	23,032
Surplus or deficit	-1,143	-2,040	-306	-2,470	-4,588	-4,061	-9,150	-5,417	-16,655	-9,107
Probability (expressed as percentages) that resources will be insufficient to meet total energy load in at least 1 period										
of Year Shown		36		53		79		79		
Years 1980-81 through year shown		36		97		100		100		
Probability (expressed as percentages) that resources will be insufficient to meet firm energy load in at least 1 period										
of Year Shown		36		32		67		67		
Years 1980-81 through year shown		36		86		99		99		

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[a] Figures are January peak and critical period (winter) average energy in Megawatts.

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Table 2-5. Hydroelectric projects on the Lewis and Cowlitz rivers, tributaries to the lower Columbia River.

Project	Operator	River	Capacity (MW) Existing	Capacity (MW) Planned	Planned additions	Storage reservoir (acre ft X 10^3)
Mayfield	Tacoma City Light	Cowlitz	121.5	163.0	Yes	181.5
Mossyrock	Tacoma City Light	Cowlitz	300.0	450.0	Yes	1,685.1
Packwood	WPPSS	Lake Creek	26.1		No	None
Merwin	Pacific Power and Light	Lewis	135.0	181.0	Yes	422.8
Yale	Pacific Power and Light	Lewis	108.0	216.0	Yes	401.0
Swift #1	Pacific Power and Light	Lewis	204.0		No	755.0
Swift #2	Cowlitz Co. PUD	Lewis	70.0		No	None

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The Cowlitz River facilities are the Mayfield and Mossyrock projects of Tacoma City Light, which are located on the upper river in Lewis County, about 30 airline miles northeast of the mouth of the Cowlitz and more than 50 river miles upstream from the mouth, and the small Packwood dam project of the WPPSS, located on the Lake Creek tributary to the Cowlitz. These projects are well outside the study area as defined in Section 2.1.2. Nevertheless, the Tacoma projects are large impoundments and could have some impact on the Columbia Estuary through controlled release, as for example in extreme low water conditions in the Columbia River. The situation is complicated by the present condition of the lower Cowlitz River resulting from the effects of the Mt. St. Helens eruption and subsequent dredging.

There are four projects on the Lewis River (see Table 2-5); two are on the Cowlitz-Clark County line, on the edge of the study area. Merwin, Yale, and Swift dams are operated by Pacific Power and Light (PPL), and Cowlitz Co. PUD receives flow from Swift dam at a second Swift generating facility. PPL's license for the Merwin project was issued in 1929 and expired December 11, 1979. The utility applied for relicensing, but was challenged by Cowlitz Co. PUD, which claimed preference by virtue of being a public utility. No precedent exists for such a claim in a relicensing situation, and the case is currently in litigation (Robinson, Cowlitz County PUD; pers. comm.). Potential further development of the Lewis River projects is discussed in Section 2.2.3.1.

2.2.2.2 Thermal-Electric. There are two large thermal-electric generating facilities in the study area, both located on the Columbia River in Columbia County, Oregon. They are the Trojan Nuclear Power Plant near Rainier, and the Beaver Combined Cycle Generating Plant near Clatskanie. Both were built and are operated by the Portland General Electric Company (PGE).

2.2.2.2.1 Trojan Nuclear Power Plant. The Trojan Plant is located 4.5 miles southeast of Rainier, between the small communities of Prescott and Goble. The site, owned by PGE, occupies 635 acres between the Columbia River and U.S. Highway 30. The plant site proper is a bedrock formation, 45 feet above sea level. The main plant complex, including the switchyard, occupies about 50 acres. The remainder of the site comprises the half-mile-radius utility owned clear zone required by the National Regulatory Commission standards (Carter, PG&E, pers. comm.).

The plant consists of a single pressurized water reactor unit and steam turbine generators having a net electrical output of 1,130 MW. Water taken from the Columbia River at an intake structure at the east end of the plant complex is used to replenish blowdown at the condensers and losses at the cooling tower. Approximately 19,700 gallons per minute (gpm) are taken from the river; 8,700 gpm are returned as diluted discharge from the third cycle, and the remainder (11,000 gpm) is lost through evaporation from the tower. The average flow of the Columbia River at this point is about 100 million gpm (PGE 1978).

2.2.2.2.2 Beaver Generating Plant. The Beaver Plant of PGE is located at Port Westward, aproximately five miles north of Clatskanie at about river mile 53.

When the units went into operation in August 1974 and November 1977, they used primarily #2 fuel oil, delivered by ship from the Puget Sound refineries. With recent upgrading of the Northwest Natural Gas pipeline from Deer Island to Astoria (see Section 2.4.2), PGE expects to switch to gas fired operation at the Beaver Plant. The Northwest Natural Gas Company supplies roughly 50 percent from Canada and 50 percent from the San Juan Basin. There is no present or contemplated use of the gas now being produced in the nearby Mist Field near Vernonia in Columbia County (Dyer PGE; pers. comm.). PGE is studying the development of coal gasification at Beaver (see Section 2.3.4, Potential Processing Facilities).

Beaver functions as an intermediate power facility, meaning that its use falls somewhere between continuous base load generation and peak power use. Although the expense of oil and gas tend to drive it into peak use, it is one of the first facilities to come on line when loads increase (Dyer, pers. comm.).

Beaver was built as a back-up to Trojan, and its site offers several advantages (Dyer, pers. comm.). When Trojan is shut down, Beaver comes on line and puts power into the grid at roughly the same point. Also, the site has marine access to the world market for oil (although oil has become less economical to use).

2.2.2.2.3 Other facilities. There are no other thermal-electric generating facilities of significant size in the study area. A few communities have small, conventional (steam or diesel) plants that serve as backup facilities, with little or no regular use. A 26 MW plant at Longview and an 8,000 kW plant at Astoria are shown on the BPA Electric Power Plants map.

2.2.3 Potential Development

2.2.3.1 Hydroelectric. There is clearly renewed interest in hydroelectric power in the Pacific Northwest, as an old but not yet fully utilized renewable energy resource. This interest is seen in efforts to complete the Columbia River Hydropower System, including the addition of peaking capacity to major projects, and also in studies, legislation, and widespread discussion about the development of new, mostly small or medium hydro projects at previously undeveloped sites on small rivers and tributaries.

Both the U.S. Army Corps of Engineers and the Water and Power Resources Service (WPRS) are completing surveys of potential, undeveloped hydro sites. The U.S. Army Corps of Engineers is concentrating on previously identified sites of all sizes, whereas WPRS is focusing on low-head (20 meter or less) sites of 1 MW or more potential. These additions to baseline information, together with incentives and favorable policies reflected in federal small hydro loan programs, federal and state tax incentives, recent legislation requiring utilities to purchase from small producers, and favorable state policies, state surveys, and state bonding programs provide strong impetus to further development of the small hydro resource. Weighing these and additional practical, institutional, and legal factors, it appears that conditions are becoming more favorable for small-to-medium hydroelectric development, but that this does not imply a general proliferation of development now, or in the future. It does suggest that small hydro development has a reasonable likelihood of occurring where attractive sites are available and investors are interested in taking advantage of them.

2.2.3.1.1 U.S. Army Corps of Engineers Inventory. Thirty-four sites have been identified by the U.S. Army Corps of Engineers on tributaries of the lower Columbia, excluding the upper Cowlitz River in Lewis County. Excluding sites already developed, sites eliminated by the Mt. St. Helens eruptions, and sites screened out for economic, engineering, or environmental reasons, four undeveloped sites remain active in the inventory. These are listed in Table 2-6. Three of these sites are diversion projects involving small dams with substantial power head and capacity. The fourth, Tum Tum, requires a high dam and would be classified as a fairly large hydroelectric project.

The U.S. Army Corps of Engineers Inventory is not exhaustive, covering only those sites that had previously been identified. It probably encompasses most of the larger sites, but perhaps only a fraction of the small sites down to the 1 MW lower limit of the inventory. Only four sites in the one to two MW range were identified in the study area, and they were among the ones classified as inactive. There probably are other potential sites for small hydroelectric development in the study area, but without

Table 2-6. Undeveloped hydroelectric power sites in active status in the U.S. Army Corps of Engineers National Hydroelectric Power Inventory.

Project	Location	Power-head (ft)	Dam height (ft)	Impoundment (ac/ft)	Total capacity (kW)
Charter Oak	East Fork, Lewis River, Clark County	250	10	negligible	26,800
Tum Tum Mountain	Canyan Creek, Clark County	515	315	82,700	36,200
Pigeon Spring	Kalama River, Cowlitz County	679	10	negligible	16,131
Grays River	Grays River, Nahkiakum County	230	50	1,900	17,000

the depth of information the U.S. Army Corps of Engineers is developing for its identified sites, it would be impossible to specify these.

2.2.3.1.2 Actively Proposed Hydroelectric Project. Three active proposals for hydroelectric projects have been identified within the study area; these are listed in Table 2-7.

Gray's River. The Gray's River proposal is at the site identified in the U.S. Army Corps of Engineers inventory. On November 4, 1980, Wahkiakum County PUD No. 1 filed an application for a Preliminary Federal Energy Regulatory Commission (FERC) Permit, reserving the site (FERC 1980). The PUD is serious about proceeding with the project.

A preliminary feasibility report has been prepared by R. W. Beck & Associates (1980). The project would consist of: (1) a concrete diversion dam 50 feet high, including a central uncontrolled spillway and fish passage facilities; (2) a concrete lined power tunnel 10 feet in diameter and approximately 11,200 feet long; (3) a powerhouse containing two vertical shaft Francis-type turbines and generators having a total installed capacity of 17 MW located in the lower reaches of the gorge area; and (4) a new 115-kV wood pole transmission line extending from the power site 6.5 miles southwesterly to the Naselle-Cathlamet 115-kV line.

The 50-foot dam proposed for Grays River is in conflict with Washington's Columbia River Fish Sanctuary Act. The PUD has not yet applied for State permits; however, the Washington Department of Ecology (WDOE) has reviewed the FERC permit application and plans to take issue with it over the height of the dam. The PUD is expected to request an exemption. WDOE indicates that there may be some room for negotiation or reinterpretation of the law and/or for the proposer to bring the latter into compliance (Egbers, WDOE; pers. comm.).

Merwin. As described in 2.2.2.1, Cowlitz County PUD No. 1 is contesting PPL's relicense. If successful, the PUD says it plans to build an additional powerhouse at Ariel Dam. The U.S. Army Corps of Engineers

Table 2-7. Proposed hydroelectric projects in the Colubmia River study area.

Utility or individual	Project site	Proposed development
Wahkiakum Co. PUD No. 1	Grays River	Dam, diversion, powerhouse
Cowlitz Co. PUD	Merwin	Additional unit to existing dam
Frank Hansen	"Hansen" North Fork Lewis	Spill over dam, diversion, generator

inventory indicates that 45 MW of additional capacity exists; the PUD claims that 80 MW is available. No formal license applications have been made pending outcome of the relicense litigation (Robinson, pers. comm.).

Frank Hansen. This project is an example of the very small hydro applications which are increasingly generated by individuals at sites too small to have been included in the U.S. Army Corps of Engineers inventory. This project, on the North Fork Lewis River near Woodland, would be built on the applicant's property. A below surface dam and diversion structure would span the stream; the power capacity would be 100 kW. The WDOE representative foresaw no major problems in state permit approval (Egbers, pers. comm.).

Based on the survey sites identified by the U.S. Army Corps of Engineers and the current proposals, an estimate of hydroelectric development probabilities was made and is presented in Table 2-8 as a probability matrix.

2.2.3.2 Thermal-electric. Officials of major utilities and the Washington Energy Facilities Site Evaluation Council indicate it is extremely unlikely that any more large thermal plants will be built in the western portion of Oregon or Washington. The only possible exception might be the construction or expansion of a nuclear plant at an already proposed or established site, such as Satsop or Trojan.

Table 2-8. Probability matrix for hydroelectric development in the lower Columbia River and Estuary.

	Time frame		
Projects/sites	1981-1986	1987-1996	1997-2006
Grays River	low	medium	low
Merwin, 2nd Unit	low	medium	medium
Yale, 2nd Unit	low	medium	medium
Hansen	high	low	low
Charter Oak	low	medium	medium
Tum Tum Mountain	low	low	medium
Pigeon Spring	low	medium	medium
Other "Micro-Hydro" (<1,000kW), sites unspecified	medium	medium	medium
Other Small-to-Medium Hydro (1,000-30,000 kW) at sites unspecified	low	medium	medium

PGE and PPL (Dyer, pers. comm.; Smith, PPL; pers. comm.) were asked about any short or long range plans for development in the lower Columbia. PPL indicated that it has no plans. PGE stated that no coal plants would be built on the lower Columbia.

PGE is keeping open certain options for its sites at Trojan and Beaver, which could at some time involve additional units. Trojan was originally planned for two units, and the site could accommodate another unit if an additonal 600 acres downstream of the present site were purchased (Carter, pers. comm.). Expansion at Beaver is by far the most likely, since ample land is already available, gas combustion presents few environmental problems, and Beaver is ideally suited to relieve the larger thermal plants of peaking capacity.

The Washington Energy Facilities Site Evaluation Council knows of no proposals for new sites on the lower Columbia River in Washington; the major site certification expected in the state in the 1980's is Creston (Fitch, Washington Energy Facility Site Evaluation Council; pers. comm.)

Cowlitz County PUD #1 owns a site on the Columbia River at Kalama, immediately south of the grain terminal. This was acquired several years ago for a possible nuclear plant, but proved to be too small and deficient in other respects. The PUD states it has no current interest in developing the site (Robinson, pers. comm.).

Based on the foregoing information, an estimate of development probabilities is presented in Table 2-9.

Table 2-9. Probability matrix for thermal-electric developments in the lower Columbia River and Estuary.

Projects/site	Time frame 1981-1986	 1987-1996	 1997-2006
Beaver, additional unit(s) combined cycle	low	high	medium
Trojan, additional unit, nuclear	---	---	low

2.3 FUEL PROCESSING FACILITIES

2.3.1 Background

The processing of fuels includes: (1) refining, generally of crude petroleum; (2) physical changes of state such as liquefaction or regasification of liquid natural gas (LNG) or liquid petroleum gas (LPG); (3) physical and chemical changes of state involved in synthetic fuel production; (4) biomass conversion for production of alcohol fuels; and (5) refining and processing of nuclear fuels and nuclear waste.

Some of these types of processing are directly related to and involved in the transportation of energy, for example LNG regasification at a marine receiving terminal. Some processing facilities are often conveniently located at the site of transportation facilities, such as oil refineries at a marine terminal/pipeline interface, but are not necessarily sited at these locations, depending on various market-economic locational factors. All types of processing involve the transport of input fuel commodities and output products from the processing site. Section 2.4 on energy transportation facilities should, therefore, be reviewed in conjunction with the material presented in this section.

2.3.1.1 Refining. Refining involves a series of processing steps that convert crude oil into different types of petroleum products, such as asphalt, solvents (e.g., naptha), residual fuel oils (for industrial use), distillate fuel oils (home heating and diesel), kerosene, jet fuel, and automotive and aviation gasolines.

Projected increases in Northwest demand for oil products, particularly heating oil and gasoline, have been strongly moderated by dramatic price increases in the past decade. It appears reasonable to assume an essentially stable level of consumption during 1981 to 1986 at about 450,000 b/d, and from then on a widening range around this figure but biased toward some potential growth in consumption (e.g., 425,000 to 525,000 b/d in 1987 to 1996, and 400,000 to 600,000 b/d in 1997 to 2006).

About three-fourths of the region's petroleum supply arrives as crude by tanker from Alaska and overseas foreign sources. Presently almost all of this supply is received at four major refineries at Cherry Point and Anacortes on Puget Sound, which in 1975-76 produced about 71 percent of the petroleum product consumed in the three Northwest states, and nearly all the product consumed in western Washington and Oregon (OIW 1975).

One-fourth of the Northwest's petroleum supply arrives as product from refineries outside the region, Billings and Laurel, Montana, and Salt Lake City, Utah, via the Yellowstone Pipeline (Billings to Spokane and Moses Lake) and the Chevron Pipeline (Salt Lake to Boise, Walla Walla, and Spokane) (PNRC-NEPP 1978).

About 60 percent of the output of the Puget Sound refineries is distributed via the Olympic Pipeline from Bellingham to Seattle and Portland, and the Southern Pacific Pipeline from Portland to Eugene. Most of the remaining product is shipped by tanker or barge, about half of this to California and other destinations outside the Northwest, and half to Pacific Northwest destinations (of this about one-fifth to Oregon destinations, four-fifths to Washington). The Columbia-Snake waterway represents a small but significant part of the distribution system for petroleum products. Table 2-10 shows the breakdown of these supplies (PNRC-NEPP 1978).

There are currently no facilities for petroleum refining in the lower Columbia River study area. The nearest such facility is a small, 14,000 b/d Standard Oil Company asphalt refinery in Portland, which is also the only refinery in the state of Oregon (OSU Sea Grant 1978). Recent and

Table 2-10. Average barrels per day (b/d) of refined petroleum consumption or shipment from various sources in the Pacific Northwest in 1975-76.

Sources	b/d
Total consumption: Washington, Oregon, Idaho	408,000
Production of Puget Sound refineries	288,000
(approximately 80% of capacity)	
Other sources of refined products	120,000
(primarily Yellowstone and Chevron pipelines)	
Shipments from Puget Sound refineries	
Via Olympic and Southern Pacific pipelines	171,000
Via tanker/barge	
Total	117,000
To Pacific Northwest destinations	60,000
Shipments on Columbia/Snake system[a]	16,000

[a] Primarily from the Puget Sound refineries - both by direct marine shipment and from the Olympic pipeline at Portland.

past proposals for refinery development in the study area are discussed in Section 2.3.2.1.

The Washington Offshore Petroleum Transfer Systems study did not consider the Columbia River area as a site for major oil transfer to long distance pipelines. Depth at the Columbia River Bar and all points upstream is insufficient for even medium size tankers and cannot accommodate the 70- to 90-foot draft of a supertanker. Such depths are available, or attainable, at Puget Sound ports such as Cherry Point and Port Angeles. The study did consider offshore sites for oil transfer, such as a site six miles from the entrance to Grays Harbor; however, this was rejected on the basis of cost and wave climate. No such possibility was considered for the mouth of the Columbia River where wave climate and costs would be comparable.

The possible future development of Outer Continental Shelf (OCS) oil production off the Oregon or Washington coast could at some time lead to the construction of refineries in the vicinity of onshore receiving, treatment, and storage facilities. As discussed in Section 2.5, Extraction, there are some limited prospects for oil and gas discovery in the thick sediments located off the Columbia River mouth.

2.3.1.2 Liquified natural gas. Interest in LNG and LPG development stems from their potential as alternative energy sources or as means of supplementing uncertain future supplies of natural gas. In 1977 the Washington Legislature authorized a study of LNG and LPG systems and facilities, associated hazards, and siting considerations. This study, conducted by the Oceanographic Institute of Washington (OIW 1978b) was entitled "LNG and LPG Hazards Management in Washington State". The report includes detailed analysis of hypothetical facilities and hazards at several Illustrative Sites, one of which is Cottonwood Island on the lower Columbia River, which is also the site of an LNG proposal that was active at the time of the study.

Natural gas supplies have improved despite the forecasted shortfalls and declining demand projections of the mid-1970's, and gas consumption has not exhibited the sharp downturn which has characterized petroleum consumption since 1979. Gas is increasingly viewed as a preferred fuel, and conversion from oil, or in some cases electricity, to gas is evident on the part of industry, utilities, and domestic consumers. Thus, at least moderate growth in demand can be expected during the 1997 to 2006 period. Nevertheless, the fairly definite prospect of a shortfall posed by the threatened 1989 cutoff or major reduction in Canadian supplies, might persuade gas companies to take precautionary measures such as the development of marine terminals for LNG importation.

An LNG storage facility exists at Newport, Oregon. Inadequate gas supplies in Oregon during the mid-1970's were the motivation for the construction of this facility by the Portland based Northwest Natural Gas Company. As originally planned, the facility was to have incorporated a marine terminal for receiving LNG shipped by tanker from the Kenai Peninsula of Alaska (Kenai-Cook Inlet gas field). Northwest Natural Gas (Goldberg, pers. comm.) believes that the terminal will eventually be built, but the timing depends on supply and price factors. Completion of the Alcan pipeline would be a determining factor, as would additional gas resources from the Rocky Mountain region.

Prospects for completion of the marine LNG terminal at Newport are significant because, if completed, the facility could increase Oregon's gas supply by 14 percent (OIW 1978b). Because of the investment already made at this deep water coastal location, it seems likely it will be the only such site developed in Oregon. Northwest Natural Gas Company believes, however, that a second terminal would probably be needed to serve the needs of the Pacific Northwest.

2.3.1.3 Liquid petroleum gas. The majority of LPG consumed in the Northwest is imported from Canada, California, and South America. The distribution of LPG is more complex than that of LNG because there is no single company involved in its importation. A number of companies have their own arrangements for meeting demands in their service areas.

Because of the nature of the industry and the lack of a pipeline distribution system, LPG is distributed in various ways. Most LPG enters the Pacific Northwest in tank cars or trucks and is distributed directly to large industrial consumers or to pressurized storage tanks (10,000 to 30,000 gallons) located throughout the region.

Hazards of LNG and LPG. Transportation and processing of LNG and LPG pose unique hazards to public safety and the environment and requires specific risk analyses be applied to the evaluation of development proposals. Since LNG is itself a cryogen, its exposure to the environment in the event of a spill could result in rapid extraction of heat from its surroundings. The vaporization and escape of LNG which would then occur could lead to the formation of a gas cloud large enough to imperil nearby land areas and populations if ignited. The hazards of LPG are somewhat similar to LNG.

LNG and LPG hazards and mitigation are treated at length in the OIW report, along with a preliminary risk analysis for the Illustrative Sites, including Cottonwood Island.

2.3.1.4 Synthetic fuels. Synthetic fuels or synfuels are synthetic organic fuel products made from coal, oil, oil shale, tar sands, and various types of biomass such as wood, grains, and garbage. Biomass conversion for alcohol production is treated separately in this report. Of the remaining raw resources, only coal is feasible for transport over long distances for processing. Because the study area is near no important oil shale or tar sands resource base, synthetic fuels production facilities using these resources will not be sited in the lower Columbia River area.

Because gasified or liquified coal is easier to transport than coal in solid bulk form (assuming that pipelines are available), it is likely that these synfuels will also tend to be produced near the sites of extraction, which in the West are located mainly in Montana, Wyoming, and North Dakota. However, if large supplies of coal start moving through the Columbia River area, small quantities might be diverted to localized, small scale synfuel production facilities. These facilities would probably be located near other existing energy related facilities that could utilize the rather specialized products of synfuel production. A syncrude oil facility, for example, might locate near a petroleum refinery which could use some of the syncrude product as feedstock in refining. The PGE has proposed a coal gasification plant at Port Westward, which would provide medium-Btu synthetic gas for its combined-cycle generating plant there.

It seems unlikely, that large scale synfuel production will develop in the study area to supply the region's major consumption demands for gas and oil, even if the most pessimistic supply projections for natural sources of these fuels are realized. Such large scale development might occur east of the Cascades or near the site of coal extraction. The prospects for coal export, which would bring more coal through the area, are examined in Section 2.4.

2.3.1.5 Biomass conversion (alcohol fuels). There is interest in the U.S. in the partial replacement of petroleum fuels with renewable fuel resources based on biomass. Alcohol fuels produced from biomass are of two types, ethanol (or grain alcohol) produced from crops or crop wastes (e.g., grain, potatoes, sugar beets, fruits, etc.), and methanol (wood alcohol) produced from cellulose. The largest source of biomass in the Northwest is forest products waste, and large scale alcohol fuel production would most likely be cellulose based manufacture of methanol. Expert opinion is divided as to the economic feasibility of alcohol fuels and the net energy gain.

There is extensive interest in the agricultural community of Oregon for developing alcohol fuel production as a means of obtaining a measure of energy self-sufficiency. Large farm enterprises and cooperatives are starting to make sizeable investments in this technology.

PGE (Dyer, pers. comm.) believes that an export market could develop for large-scale methanol production in the Northwest. Japan is very interested in importing methanol, because of its severe air pollution problems which would decrease with the use of methanol rather than coal. Methanol contains higher Btu's per unit of weight than coal, which makes it attractive for long distance transport of large quantitities. Nevertheless, coal is currently cheaper for Japan to import.

2.3.1.6 Refining and processing of nuclear fuels and waste. No facilities for either processing of nuclear fuels or waste reprocessing exist or are planned within the study area. The one nuclear facility, the Trojan Nuclear Power Plant, receives truck shipments of fuel assemblies produced at the Savannah River Plant in South Carolina. Spent fuel is presently stored on the Trojan site (Carter, pers. comm.).

The Hanford Reservation on the Columbia River near Richland, Washington is a national center for storage of nuclear wastes, and a reprocessing waste solidification program is in progress. An initiative passed by Washington voters in November, 1980 will limit Hanford's acceptance of nuclear wastes from other states, unless preempted by federal mandate.

2.3.2 Potential Development

2.3.2.1 Refining. During the mid-to-late 1970's, several proposals were made for refinery development in the lower Columbia River area in Oregon. These are listed in Table 2-11.

The first three proposals, and apparently the last, were for small-to-medium size, low-complexity refineries to be supplied with crude by small tankers or barge lighters. The Washington Offshore Petroleum Transfer Systems Study (OIW 1975) discussed these proposals, stating that they appeared to be based on prospects for an increased market for industrial fuel oil in the Pacific Northwest as a result of shortages in natural gas supplies forecasted for 1975 -- shortages which have not materialized.

Irrespective of the current status or possible future realization of any of these specific proposals, they indicate that any refining industry that might develop in the lower Columbia River would probably be on a relatively small scale, serving a subregional and/or limited industrial-sector market, as a supplement to the existing refineries on Puget Sound. There does not appear to be a strong economic motivation for even this type of refinery development.

There is a significant, though not high, probability that one small-to-medium size (25,000 to 100,000 b/d) refinery development will occur in the study area in the next 15 years, a lesser probability that two such developments might occur, and little or no probability of a third. Extending the horizon to 25 years alters the picture very little; there is a slight possiblity that as many as three small-to-medium refinery developments could occur by then. These probabilities are shown in Table 2-12.

An indication of likely locations for development is provided by refinery proposals to date and by the existence of suitable sites that conform to local plans and policies. The fact that at least two proposals pertain to the Dibblee Point-Rainier site indicates its apparent attractiveness for refinery development. According to the Port of St. Helens (Gainer, Port of St. Helens; pers. comm.), the Port is currently working with the City of Rainier to get sewer and water connections to the site, which was recently annexed by the City.

In terms of site suitability and conformance to local plans and policies, Dibblee Point-Rainier, Deer Island, and Port Westward are probably the most attractive on the Oregon side. Other industrial sites in Columbia County identified by Norris (1975) and by the Columbia County Comprehensive Plan (1980) should also be noted, for example, Trojan, South St. Helens, and Scappoose. Columbia County and the Port are clearly oriented toward diversified economic growth that takes advantage of port sites and rail/highway access.

In Clatsop County, in the Astoria-Warrenton-Hammond area, a few shoreline sites have sufficient level area for refinery development, most prominently the south shore of Young's Bay, the Skipanon River mouth, and Tansy Point. The area could conceivably become a candidate for some

Table 2-11. Status of proposed refineries in the lower Columbia River study area.

Proposer	Location	Size (b/d)	Status	Comments
Columbia Independent Refiners, Inc.	Portland Rivergate Industrial Park	50,000 to 100,000	Abandoned	
Charter Energy Co.	St. Helens	52,000	Renewal of permits requested 1976	Not mentioned by officials of Port of St. Helens during survey.
Cascade Energy, Inc.	Ranier/Dibblee Point	30,000	All permits in order 1977	Port of St. Helens own half the site. Again, not mentioned.
Caribou Four Corners Oil Co.	Ranier/Dibblee Point	unspecified	Abandoned	Financing problems.

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Table 2-12. Probability matrix for refinery development in the lower Columbia River.

Refinery	Time frame		
	1981-1986	1987-1996	1997-2006
First	low	medium	medium
Second	---	low	low
Third	---	---	low

refining industry in the unlikely event that OCS oil production develops off the mouth of the Columbia. Few other sites exist in Clatsop County.

Pacific and Wahkiakum Counties in Washington are clearly not oriented toward development of heavy manufacturing or processing industries at this time. Both Pacific and Wahkiakum Counties lack the infrastructure for major industrial development. There is no railroad along the Columbia River in either county (none at all in Wahkiakum), and major stretches of the river lack highway access. Power and other utilities are relatively limited, and suitable sites are also very limited. Pacific County has only one sizeable level area on the estuary, near the mouth of the Chinook River. In Wahkiakum County the only level shoreline areas of significant size, not contained in wildlife refuges, are at the mouth of the Grays-Deep Rivers and Puget Island/Little Island, which are prime agricultural areas.

Cowlitz County presents an entirely different picture. This county is the most highly industrialized area of the lower Columbia River below Portland and has a transportation and utilities infrastructure (see Section 2.4). Extending along much of the county's riverfront, there is a string of mainland and island sites which are designated by the U.S. Army Corps of Engineers as dredge disposal for volcanic ash from Mt. St. Helens. The majority of these sites are either zoned industrial, or classified urban in the County's Shoreline Master Program, or both, reflecting a policy apparently strongly favorable to industrial development (Deatherage, Dept. of Community Relations, Kelso, Washington; pers. comm.).

Cottonwood Island, a prime U.S. Army Corps of Engineers disposal site, is being promoted for development. Various energy related activities have been mentioned, including coal transshipment, LNG receiving, synthetic fuels production, and refining.

Cottonwood Island has major advantages from the standpoint of deep water. The site has three miles of frontage on the ship channel, rail and highway access, and proximity to the Northwest Natural Gas pipeline. By the end of 1981, the U.S. Army Corps of Engineers will have raised the elevation of the island by 20 feet, bringing it above the 100-year flood plain (Deatherage, pers. comm.).

Of all the sites mentioned for refinery development, the following are judged most likely and are listed according to likelihood: Dibblee Point-Rainier, Deer Island, Port Westward, Cottonwood Island, and Kalama.

2.3.2.2. Liquified natural gas. Based on analysis of market conditions and potential future natural gas supplies, there is a medium-to-high probability that one marine terminal for receiving, storing, and regasifying LNG will be built in the Pacific Northwest during the next 25 years, in addition to completion of the LNG facility at Newport, Oregon. The terminal would probably be built in Washington, but there is only a low probability that it would be built on the Columbia River because other, probably more attractive, sites exist on Puget Sound and perhaps elsewhere.

The OIW (1978b) prepared matrices for the evaluation of hazards and jurisdictional issues and identified seven preliminary site areas in the Columbia River area below Bonneville Dam: one each in Skamania and Clark Counties, four in Cowlitz County, and one in Wahkiakum County. It is clear from the hazards matrix that all the Columbia River sites are fairly comparable, but have more hazards potential than the sites elsewhere in Washington.

No site areas were identified by OIW in the lower Columbia River Estuary. Topographic conditions on the Washington side are generally unsuitable. Plausible sites do exist on the Oregon side in the Astoria (Warrenton-Hammond) area as well as the upstream Columbia County port sites, especially Port Westward.

The cumulative probabilities for development of LNG marine terminal/regasification facilities on the lower Columbia River are forecasted in Table 2-13.

2.3.2.3 Liquified petroleum gas. Although future growth in demand for LPG is questionable, predicted future surpluses in foreign production and attractive prices indicate a medium-to-high probability that marine receiving terminals will be built in the Pacific Northwest, in addition to the existing LPG terminal at Ferndale, Washington. Because these facilities are smaller and less elaborate than LNG terminals and do not require pipeline system connection, more of them are likely to be built in

Table 2-13. Probability matrix for LNG development in the lower Columbia River and Estuary.

Facility	Time frame		
	1981-1986	1987-1996	1997-2006
First	---	low	low
Second	---	---	---

more places, increasing the likelihood of one or more developments on the Columbia River. Most port sites in Oregon or Washington would be suitable.

Because LPG is typically carried in smaller vessels than petroleum or LNG, the upriver sites closer to markets may have a relative advantage. For this reason, Portland and Vancouver may also be probable terminal sites. Since pipeline access is not a factor, Cottonwood Island and some other sites in Cowlitz County do not have an advantage in this respect for LPG as they do for LNG. Since certain types of LPG are used as feedstocks, refinery development at Rainier or elsewhere would likely attract an LPG terminal. Cumulative probabilities for LPG terminal facilities on the lower Columbia River are given in Table 2-14. In the absence of more definite development proposals, the probability that any one identified site will be developed for LPG is low. Vancouver/Portland, or their environs are the most likely candidates, followed by Port Westward and Rainier.

2.3.2.4 Synthetic fuels. The only known proposal for synfuels production in the study area is the tentative plan of the PGE to develop a coal gasification facility at its Beaver Generating Plant at Port Westward. The medium-Btu gas produced would be suitable for use in the combined-cycle combustion turbines of the Beaver Plant.

Development of coal gasification at Beaver would entail an approximate doubling of the existing plant structure. Port Westward is, thus, the most probable near-term site for synfuels production (low probability for 1981-1986; medium-to-high probability for 1987-1996).

Other possible sites would be anywhere that refinery development is likely to occur (e.g., Dibblee Point-Rainier, Cottonwood Island, Deer Island, and other sites in Cowlitz and Columbia Counties).

2.3.2.5 Biomass conversion (alcohol fuels). Location of biomass conversion facilities is highly speculative, and proposals are far from firm. The lower Columbia River area is not close to any major agricultural areas which could supply input resources for ethanol production. No such facilities are projected to be constructed in the study area in the next 25 years.

Table 2-14. Probability matrix for LPG development in the lower Columbia River and Estuary.

Facility	Time frame		
	1981-1986	1987-1996	1997-2006
First	low	medium	medium
Second	---	low	medium
Third	---	low	low

2.3.2.6 Refining and processing of nuclear fuels and waste. No future development of new nuclear materials processing sites is forecasted for the study area, with the possible exception of some spent fuel handling at the Trojan Nuclear Plant. Hanford will continue to be a major site for the processing and storage of nuclear waste.

2.4 TRANSPORTATION AND TRANSSHIPMENT FACILITIES

2.4.1 Background

The fixed infrastructure for the movement of commercial amounts of energy from one point to another (e.g., electric power transmission lines, natural gas pipelines) and for marine and vehicular movement of fuels (e.g., shipment of coal, oil, and liquified natural gas) is critical to energy development. For purposes of this discussion, also included in this category are the physical plant facilities (power stations and substations, coal storage yards, tank farms, etc.) required for the transmission of power or movement of fuel materials.

As discussed in Section 2.5, the Pacific Northwest in general, and the lower Columbia River region in particular, lack significant known sources of energy producing minerals. However, the Columbia River system has a natural advantage as a transportation corridor which, up until now, has been used primarily for the movement of grain and general cargo, by both ship and rail. With the prospect of increased extraction of energy and energy fuels from the Rocky Mountain area, and the development of export markets in the Far East, the lower Columbia River region is expected to see an increased share of fuel movement.

2.4.2 Existing Facilities

2.4.2.1 Electric power transmission lines. Lines of 500 kV or greater voltage exist along the Columbia River only upstream of the Trojan Nuclear Plant near Rainier. There are currently 500-kV lines between Trojan and Portland, Trojan and the Willamette Valley, and Trojan and Chehalis, Washington. The Trojan-Chehalis line includes a submarine cable crossing of the Columbia River at Trojan. Lines of lower voltage run generally along the Columbia River on both sides of the river. Four lines span the river in an aerial crossing at Longview (river mile 62.5). Below Trojan-Longview, there are two 230-kV lines on the Oregon side, one running as far as Wauna, the other all the way to Astoria. On the Washington side, there is a 115-kV line between Cathlamet and Naselle, several miles north of the estuary. There is currently no major power transmission line between Cathlamet and Longview. Cathlamet is served by an aerial transmission line crossing of the river at Puget Island (river mile 49), connecting to one of the Oregon lines. Submarine cables cross the estuary from Astoria and Hammond to Ilwaco.

2.4.2.2 Natural gas pipelines. The primary natural gas supplier in the region, Northwest Pipeline Company, obtains gas from Canada and the southwestern United States for sale to private gas utility distributors. Northwest Natural Gas Company now has a 16-inch pipeline entering Oregon from Washington via a submarine crossing at Deer Island. The pipeline system branches at Deer Island, with one line running south to serve St. Helens and Scappoose, while the other line runs northwest along the river to Astoria. There is also a short line connecting Reichold Chemical with the mainline. A new pipeline has been built by Northwest Natural Gas connecting its new gas field at Mist with the main pipeline near Clatskanie. The line consists of nine miles of 12-inch pipe, with a maximum capacity of 50 million cfd. Currently, the Mist fields consist of five wells, producing 20 million cfd of natural gas. On the Washington side, only the Northwest Pipeline Company's north-south line from Canada approaches the lower Columbia study area. It roughly follows the river from Longview-Kelso to the East Portland area.

2.4.2.3 Oil pipelines. In western Washington and Oregon, petroleum products are piped from refineries in the Puget Sound area to Portland via the Olympic Pipeline, and south to Eugene, Oregon, via the Southern Pacific Pipeline. The Olympic Pipeline parallels the Columbia River on the Washington side from the Longview area to Vancouver, with submarine crossings at Sauvie Island and Hayden Island (Portland).

2.4.2.4 Railroads. Between Portland and Astoria, Burlington Northern maintains a branch line built for light-to-moderate traffic. This line has generally good alignment and grades. The maximum gradient is 0.56 percent; the maximum track curvature, seven percent. Over most of the route a 40-mile-per-hour speed limit is in effect, with lower limits through cities and areas that have potential slide hazard. Currently, three trains per day run between Portland and St. Helens, with one continuing on to Astoria. Considerable expense would be incurred in upgrading the line to heavy-duty hauling capacity (Bartl and Morgan 1981).

On the Washington side, rail service between Vancouver and Kelso consists of the main Portland-Seattle line, capable of carrying heavy-duty traffic. Currently, this line is used by both the Burlington Northern and Union Pacific Railroads. There is no rail service along the Columbia River downstream of Kelso-Longview on the Washington side.

2.4.2.5 Highways. Portland and Astoria are connected along the Columbia River by U.S. Highway 30, a principal arterial highway. Although Highway 30 is well maintained and has been improved over the years, it passes through all population centers along the river, including downtown Astoria. In view of the State Transportation Department's policy of maintaining existing roads in preference to building new ones, it is unlikely that bypasses around the cities will be built in the foreseeable future. The resulting constraint upon heavy-duty hauling of energy materials could be substantial.

On the Washington side of the river, Interstate Highway 5 connects Portland-Vancouver and Kelso. Below Kelso, Cowlitz and Wahkiakum Counties are served by Washington State Highway 4, which parallels the river as far as Cathlamet. Highway 4 is generally a good quality road; however, it has not been improved significantly in many areas and should be considered a medium-duty highway. From Cathlamet to the northern end of the Astoria-

Megler Bridge, there is no continuous highway access to the river. A portion of U.S. Highway 101 follows the river from Megler to Ilwaco.

2.4.2.6 River channel. The lower Columbia River is part of the Columbia-Snake rivers navigation system, extending 460 miles from Lewiston, Idaho to the Pacific Ocean. The river system is a low-level route through a high interior plateau and two mountain ranges, the Cascades and the Coast Range. Between Lewiston and Portland, slack water navigation for barges and small crafts is provided, with a maintained river depth of 14 feet. Between Portland and the Pacific Ocean, the Columbia traverses approximately 105 river miles. In this section of the river, the channel is maintained at a 40-foot depth and a 600-foot width, sufficient to accommodate loaded ships in the 50,000 dwt range. The bar at the mouth of the Columbia River is maintained at a depth of 48 feet by the U.S. Army Corps of Engineers, which is currently studying the feasibility of deepening the bar and river channel to various depths to accommodate the new generation of deep-draft cargo vessels. For ships of 100,000 dwt size, a safe bar depth of 60 feet is required. This size ship is expected to become more common in the next several years for the ocean borne movement of heavy bulk commodities such as coal. Complicating the U.S. Army Corps of Engineers' dredging operations on the lower Columbia River is the massive load of mud and ash from Mt. St. Helens that has entered the system from the Cowlitz River.

2.4.2.7 Port districts. The port districts of the lower Columbia River region include: on the Washington side, the Ports of Ilwaco, Longview, Kalama, Woodland, and Vancouver; on the Oregon side, the Ports of Astoria, St. Helens, and Portland. Most of these port districts own extensive riverfront acreage. Since much of this land is currently undeveloped and many of the lower river communities have suffered high unemployment and economic stagnation, there is vigorous competition for any potential future commodity shipments. The port districts are an important factor in attracting new shipping business to the lower Columbia. Several planned energy related transportation facilities at the Ports are described in the following section.

2.4.3 Potential Development

2.4.3.1 Coal transport facilities. There is a high probability that sizeable quantities of coal will be moved through the Northwest within the next few years. Far Eastern nations, primarily Japan, South Korea, and Taiwan, have long been energy dependent upon the Mideast oil exporters. With the volatility and increasing cost of that market, these industrial countries have, in the last few years, begun to look elsewhere for their energy needs.

With the recent surge in popularity of the vast U.S. coal reserves, along with the pressure from our government on Far East countries, especially Japan, to help ease our balance-of-payments deficit, it is likely that large amounts of western subbituminous coal will be sold to those countries in the next two decades.

Coal from the Rocky Mountain states, primarily Wyoming and Montana, will be transported to the Northwest, to a deepwater port for shipment overseas. Rail, water, slurry pipeline, or some combination of these transportation modes would be employed in the lower Columbia River area.

2.4.3.1.1 Rail. The Port of Astoria is actively seeking to establish a coal transshipment for potential Far East markets. Prospects appear good. The most likely means of moving the coal to Astoria would be on unit trains, of approximately 100 cars each, for at least the final 100 miles on Burlington Northern's Portland-Astoria branch line. To accommodate these long, very heavy trains, that would be necessary for economical operation of a coal terminal, three to five per day, the tracks would require significant upgrading, especially below St. Helens. Rerouting of tracks in at least three areas between Portland and Astoria would be necessary to mitigate the inherent noise pollution and traffic problems.

It appears likely that, if coal export from the Northwest at the Port of Astoria does prove to be economically feasible, the most likely location for the terminal would be at Tongue Point, but not until later in the decade. The State of Oregon has entered into an agreement with the Port of Astoria wherein the Port will act as the marketing agent for the State in finding a client to develop and operate a coal terminal at Tongue Point.

The site most likely to have an operational coal transshipment terminal in the near future is owned by the Port of Kalama, Washington. The location is a 200-acre area on the Columbia River immediately to the north of the Kalma River at about river mile 72. This project is proposed as a joint effort of the Port of Kalama and Pacific Resource, Inc., a Hawaii-based energy company. The Port, through its contractor, and the Portland District of the U.S. Army Corps of Engineers are preparing the required Environmental Impact Statement, which is scheduled to be completed in mid-1981. In summary, a marine coal terminal, with a capacity of 15 to 20 million tons per year supplied by unit trains from Wyoming, is proposed. Ultimately, as many as six to seven ships under 50,000 dwt would visit the terminal each week, tying up at two separate loading piers about 500 to 600 feet offshore on the edge of the 40-foot main shipping channel.

Possible rail served coal terminals at other sites along the lower Columbia include Ports Westward, Rainier, and Longview. The Port of Longview has had preliminary discussions with Burlington Northern concerning the feasibility of locating a coal transshipment terminal there. At present, there is no indication of the probability or time frame of any such development. While Longview has excellent rail service, there is a scarcity of suitable riverfront land. The Port of St. Helens owns land at both Port Westward, near Clatskanie, and Dibblee Point, west of the Longview Bridge. Most of Port Westward is leased to PGE, and Dibblee Point has been proposed for a number of energy related developments. For either of these locations, rail trackage problems associated with Astoria would also apply, but to a lesser degree because of shorter distance of track upgrading required.

2.4.3.1.2 Waterborne shipping. The Columbia-Snake rivers system has long provided a convenient and economical means of shipping commodities. The lower Columbia River, between Portland and Astoria, carries both barge and ocean-going ship traffic as allowed by its 40-foot channel depth. The upper portions of the river, above Portland, with 12- to 15-foot channel depths, are restricted to the use of barges only.

Various scenarios have been suggested to move Midwest coal down the Columbia River; however, there have been no specific proposals to move coal down the Columbia River by ship or barge. Cottonwood Island, between Longview and Kalama, has been discussed in general terms as a site for future energy related development including coal transshipment. Cottonwood Island has been receiving substantial quantities of dredge spoils and could presumably be developed into a facility to receive coal by upriver barge for transfer to ships bound for overseas markets. Alternatively, a rail spur could be built from the main Portland-Seattle line, across the narrow river channel between the Washington shore and Cottonwood Island, to a coal terminal site on the island.

For Columbia River ports to accommodate large ships, the mouth of the river and its main shipping channel must be deepened by extensive dredging, resulting in a new problem of locating additional disposal sites. Also, most harbors and ship terminals must be upgraded. Astoria is likely to be the port selected for future, very large ship coal transfers. However, if smaller, more conventional ships are used to reach potential coal exporting facilities at Portland, Kalama, or other intermediate ports, very little new development would be required. Any commercial port on the lower Columbia could, with minor modification, accommodate conventional barges. Coal would be off-loaded by crane or conveyor belt, stored, and loaded onto ocean going ships by the same means. The chances of spillage and pollution are relatively high because of the amount of handling involved. Container barges drastically minimize this problem since the commodity itself is not directly handled. Containers are transferred to and from barges by crane, or driven on and off. A large backup area is required for container handling. Most of the smaller ports on the lower Columbia River do not have enough space at the present time.

The most common mixed mode of water borne vessels employed to date have been the LASH (lighter aboard ship) and SEABEE. LASH involves a barge carrying mother vessel equipped with shipboard gantry crane designed for loading and off-loading LASH barges and lighters over the stern. A string of coal laden barges could be loaded aboard an ocean going ship directly, without the necessity of large land areas.

2.4.3.1.3 Slurry pipeline. The use of pipelines to transport coal slurry is a fairly recent development. Currently, only two coal pipelines are operational in the U.S. Coal slurry is usually a mixture of crushed coal and water pumped through a pipeline. Because of the large quantities of water required at the source, there is considerable controversy and concern over the feasibility and environmental impact of such a system originating in the Wyoming-Montana area.

Nonetheless, there are apparently at least five proposals to build new coal slurry pipelines (Lower Columbia River Development Task Force 1980). One of these, by Northwest Pipeline Company, would carry coal from Gillette, Wyoming, to Boardman, Oregon, with some 25 million tons per year to continue on to the lower Columbia region for export. However, extension of the coal slurry pipeline beyond Boardman is speculative.

2.4.3.2 LNG and LPG transport facilities. Prospects for development of LNG and LPG marine terminals and associated processing facilities are covered in Sections 2.3.2.2. and 2.3.2.3.

2.4.3.3 Petroleum transport facilities. Petroleum transport facilities include marine terminals and pipelines associated with the movement of oil from field to refinery and refined products from refinery to market. Several proposals from recent years for refineries at Rainier, Oregon are discussed in Section 2.3.2.1; a proposed oil transshipment terminal at Port Westward to move Alaskan crude oil on unit trains eastward to Northern Tier refineries has also been discussed. The company involved in this project, GATX, apparently has dropped its effort to acquire the necessary permits for such a development.

In 1977, the Cascade Energy Corporation leased, from the Port of St. Helens, 100 acres of riverfront property at Dibblee Point, west of the Longview Bridge in Rainier. The corporation had intended to develop the area for oil refining and/or transshipment of Alaskan or Indonesian crude oil to Montana refineries. Its current status is doubtful, although it has been difficult to obtain definitive information.

Major refinery development would probably entail construction of product pipelines or connection to the existing Olympic Pipeline which is east of the Columbia River from Longview to Vancouver. A small refinery might ship its product by rail or barge.

2.4.3.4 Natural gas pipelines. While no specific natural gas pipeline projects have been proposed, it seems highly likely that the existing gas pipeline network will be expanded, especially on the Oregon side of the lower Columbia River. The primary factor will be the natural gas fields currently being developed by Northwest Natural Gas Company at Mist, Oregon. As these fields are brought into a greater level of production more, or larger, pipelines may be needed to carry the gas to the company's mainline running up and down the Columbia River. As discussed in Section 2.3.2.3, there is a potential for coal gasification plants being located in the study area within the next twenty years. These plans are too preliminary to provide a basis for projecting major gas pipeline system additions in the study area. However, local pipeline connections from potential facilities to existing main pipelines can be postulated. In Oregon, examples of these would be the connections from the PGE Beaver Plant and from the Westport slough gas lease area to the Northwest Natural Gas Company Deer Island-to-Astoria pipeline; and in Washington, from the Northwest Pipeline Company mainlines to Cottonwood Island, to serve an LNG/LPG receiving terminal or other energy related development.

2.4.3.5 Electric power transmission lines. According to the Bonneville Power Administration, there are no current plans to build any major new power transmission lines in the lower Columbia region. BPA officials do not anticipate that coal transshipment facilities of Astoria and Kalama, a refinery of Rainier, or other recent development proposals would require major transmission system additions or upgrades (Williams, Schaufelberger, BPA; pers. comm.). If another need for large amounts of electrical energy beyond current capacity were to materialize, substantial upgrade could be accomplished using existing transmission corridors along both sides of the Columbia River from Portland to Longview/Rainier, and on the Oregon side from Rainier to Astoria. On the Washington side, the very low population densities and limited industrial growth philosophies of Pacific and Wahkiakum Counties preclude any need of increased electrical power capacity below Cowlitz County.

Connections would be required from potential energy related facilities to existing transmission lines. Most of these would be short. Some longer connections would be required from hydroelectric power sites such as the proposed Grays River Hydro Project in Wahkiakum County involving construction of seven miles of 115-kV line in a new corridor. This and other connections are shown in Volume II in this report.

The BPA maintains a ten-year power plan forecast for its Northwest grid, showing all improvements and modifications proposed for each year in the ten-year period. In 1980-1989, several relatively small system upgrade projects are planned for the lower Columbia region (Volume II).

2.4.4 Conclusions

Many potential developments related to the transportation of energy or fuels have been proposed. It is difficult to quantify the scope, time frame, or probability of many of these projects due to the speculative nature of discussions and the paucity of hard information. Table 2-15 presents a transportation development probability matrix.

Table 2-15. Probability matrix for transportation development in the lower Columbia River and Estuary.

Project	Time frame		
	1981-1986	1987-1996	1997-2006
Skipanon River Coal Terminal	low	low	low
Tongue Point Coal Terminal	low	high	high
Kalama Coal Terminal	high	----	----
Portland Coal Terminal	low	medium	medium
Cottonwood Island Coal Terminal	low	medium	medium
Cottonwood Island LNG terminal	----	low	low
Port Westward Syn. Gas Facility	low	medium	medium
Oregon Natural Gas Pipeline Upgrade	medium	medium	medium
Major Power Transmission Dev. -OR	low	low	medium
Major Power Transmission Dev. -WA	low	low	low

2.5 EXTRACTION FACILITIES

2.5.1 Background

Extraction refers to the recovery of fuel energy resources contained in subsurface or near surface geological formations and is limited in the study area primarily to onshore and offshore oil and natural gas wells. The lower Columbia River area and the States of Washington and Oregon in general are not considered to be an oil producing region. Historically, there has been very little extraction of geological energy resources, the only significant resource being subbituminous coal mined in Western Washington, from a field extending from King County south through Lewis County.

In the lower Columbia River area, however, there are indications that a limited commercial resource of natural gas may exist. A gas field has been discovered south of the river in Columbia County, Oregon near Mist, and a few wells are now in commercial production. A pipeline has recently been built by the Northwest Natural Gas Company to connect the Mist Field with its main gas pipeline near Clatskanie (Columbia County Comprehensive Plan 1981). Other state gas leasing is occurring in a two-township area south of Wauna (Hamilton, Oregon Division of State Lands; pers. comm.).

The presence of natural gas is also suspected in the northwest trending formations that extend from the Mist area to the Westport Slough area on the Columbia, and continue northwestward under the estuary and flood plain. State gas leasing has occurred on both sides of the river, although little or no exploration has been done as yet.

2.5.2 Potential Development

2.5.2.1 Outer Continental Shelf. The likelihood of OCS development taking place off the Oregon/Washington coast in the next 15 years, under federal jurisdiction, would appear to be quite small, considering the length of time involved in the Department of Interior lease planning and approval process and the fact that in 1977 the region was dropped entirely from the OCS schedule. The Northwest was deleted because oil companies and the U.S. Geological Service assigned it the lowest ranking of all the major offshore regions of the U.S. in terms of resource potential and desirability for leasing. The low resource estimate was based on the preliminary explorations of the 1960's and perhaps some more recent data. The assessment of low desirability was apparently based on several factors including the frequency of severe weather and high wave force conditions, high value and vulnerability of other marine resources, and possibly a strongly negative state, local, and public reaction.

Since publication of the 1977 schedule, Oregon's governor has requested that the OCS off the State's coast be placed back on the schedule (OSU Sea Grant 1978). This is consistent with other recent initiatives of the State of Oregon to encourage coastal, energy related economic development.

No similar direction is evident in Washington State relative to OCS. Deregulation of domestic oil may prompt increased or renewed interest in exploration in the region on the part of industry.

A new Pacific Northwest lease program, of moderate proportions, to accommodate such exploration is conceivable, particularly if the state policy is favorable and local Coastal Zone Management plans are accommodating. Oregon is moving in this direction. Whether exploration would lead to discovery of commercial quantities of oil or gas is, currently, entirely speculative.

Therefore, a Pacific Northwest OCS leasing program leading to exploratory activity by 1996 has a low, but not inconsequential, probability and a low-to-medium probability by 2006. Because of time requirements, there is essentially no probability of commercial OCS production within 15 years, and there is really no basis for a 25-year prediction, except that it could not exceed the low-to-medium probability for exploration. The probabilities of OCS related development in the study area are less than those stated for the Pacific Northwest coast in general and are presented in Table 2-16.

If OCS related facilities were developed in the Columbia River Estuary area, they would probably be built as close to the coast as possible, at sites on navigable waterways meeting the criteria outlined earlier. The Astoria-Warrenton-Hammond area offers the only extensive industrial port sites in the lower estuary, and these are well defined in the CREST Plan. Of these, only the East Skipanon site has been specifically mentioned in relation to OCS activity in the former Brown and Root proposal.

Table 2-16. Probability matrix for OCS oil and gas development in the lower Columbia River and Estuary.

	Time frame		
Development	1981-1987	1987-1996	1997-2006
PNW OCS	---	low	low to medium
PNW OCS commercial production	---		?
OCS related onshore activities/facilities in the Columbia River Estuary area	---	near zero	low

Drilling operations require large quantities of supplies and equipment which must be transported from the shore bases to the drilling rigs or platforms. Supply boats carry water, fuel, provisions, drilling mud, cement, drill pipe, and casing out to the rigs or platforms and bring back waste materials that cannot be disposed of offshore (MacPherson and Bernstein 1980). Crews are also shuttled back and forth by boat or helicopter. Support bases generally include docks for supply and crew boats, loading and unloading dock space, warehouses, open storage areas, a helipad, and facilities for supervisory and communications functions.

Oil rigs and platforms may be constructed at sites within the Pacific Northwest (Kaiser proposal for Grays Harbor, and a similar proposal for Port of Astoria by Brown and Root, Inc.), or may be brought in from other sites around the world. Oil or gas may be brought onshore by pipeline or may be stored offshore and transferred to vessels from floating moorings. However, a feasibility study by the OIW (1975) examined options for offshore petroleum transfer systems for Washington State and determined that because of the severe wave environment, an offshore terminal was not feasible for transferring oil. If there is OCS development in this region, the oil or gas will likely be brought onshore via pipelines, and storage and terminal facilities for transshipment, as well as at least partial processing facilities, will be required. Transshipment could be via tanker or via pipeline. Storage facilities would not have to be located near the Columbia River Estuary, but if a marine terminal were constructed for transshipment by tankers, the pipeline and storage facilities would preferably be close to the terminal. If a pipeline is used to transport oil to the east, then offshore facilities need not be near a port.

Alternatively, if wells are scattered over a large offshore area and tankers are permitted for oil transfer (and deemed feasible by the industry), then initial treatment and processing would occur on the offshore platforms. Large tankers would probably transport the crude directly to refineries equipped to handle such deliveries, probably in Puget Sound or California. Oil brought ashore by pipeline could also be transshipped into large tankers for delivery to these refineries. Such a transfer facility would almost certainly be built on the outer coast and not in the Columbia Estuary.

2.5.2.2 Onshore extraction (estuary area). Compared to OCS activity prospects, onshore extraction within the Columbia River Estuary area is much better defined (since leasing has already occurred), much more limited in the scope of possibilities, and yet still very uncertain in terms of actual resource potential and likelihood of development.

On the Oregon side, a number of companies and individuals have shown interest in acquiring tracts for natural gas exploration in the Wauna-Westport Slough area. These include major oil companies and the Northwest Natural Gas Company, which is developing the Mist Field south of the river.

This interest on the part of industry prompted the State of Oregon to conduct a lease auction on October 22, 1980, in which 42 parcels were leased, totaling about 10 square miles along the shore of, and in, the Columbia River, from the mouth of Westport Slough to Wallace Island. Although this area is partly submerged, it is mostly dry land and comes under state jurisdiction as submersible or filled lands.

Based on the concentrated pattern of high bids in one area, Hamilton (pers. comm.) surmises that the oil companies have information on the gas resources in this area that is not available to the State, and that a significant potential is indicated in at least a limited area. Hamilton expects exploration to proceed quickly, within three years or less, leading to production within five years, or not at all.

Hamilton also remarked that the gas resource probably extends into the wildlife refuge areas in the vicinity of Welch Island. The State Land Board and the U.S. Fish and Wildlife Service have a cooperative agreement for the refuge whereby the Board manages the submerged lands. Under this agreement, Hamilton thought it was quite possible that leasing could occur in the refuge, and that the Board would adhere to its policy of no drilling through water.

In Washington, a lease auction was held on March 18, 1980, in which 46 parcels on and near the Columbia River in Wahkiakum County and an adjacent portion of Cowlitz County were leased to one individual. A Washington Department of Natural Resources (WDNR) geologist (Ford, pers. comm.) expressed doubt that significant gas resources would be found in the area, indicating that a small potential exists, but probably higher on the Oregon side. Formations in the area consist of tight, well defined, narrow folds, which probably contain gas, but in minor pockets rather than in reservoir quantities. No exploration has been done by either the State or the lessees.

Ford (pers. comm.) remarked that the lessees on both sides of the river would probably put more money into the leases and exploration than they were likely to get out. He thought that the bidding behavior in Oregon was not at all unusual. The oil companies involved may have picked the area as a test case and offered high bids for a few parcels where they expected to do exploratory drilling. Ford said this was normal procedure, the bid amounts were trivial to the companies and did not suggest any special knowledge of conditions.

Based on this information and these views, it is evident that exploration activity for natural gas in the lease areas in and near the estuary is highly probable during the next five years, and less likely afterwards (because of lease terminations), although exploration may be extended to new lease areas. Some private lands are also involved. There is very little, however, on which to base a prediction that the exploration will lead to commercial production. Table 2-17 presents a probability matrix for onshore extraction activities in the study area.

Table 2-17. Probability matrix for onshore oil and gas extraction development in the lower Columbia River and Estuary.

Development	Time frame 1981-1986	 1997-1996	 1997-2006
Exploration in the Oregon lease area and adjacent private lands	high	medium	low
Commercial production in above	low	?	?
Exploration in Washington lease areas	medium	low	low
Commercial production in above	low	?	?
Exploration in other areas of the estuary	low	medium	medium
Commercial production in above	--	?	?

CHAPTER 3.0 ENERGY RELATED IMPACTS ON FISH AND WILDLIFE IN ESTUARINE SYSTEMS

3.1 INTRODUCTION

This chapter summarizes the literature on impacts of energy related facilities upon fish and wildlife in estuarine systems. This report focuses on impacts which can be related to fish and wildlife in the Columbia River Estuary. Secondary impacts due to induced growth fostered by energy developments are not discussed. For a review of these impacts see Leedy (1979) and Leedy et al. (1978). Only those impacts resulting from facilities actually identified for probable development by 2006 are discussed. Impacts of unconventional facilities are not addressed.

Impacts are discussed to the extent that they influence air, water, soils, vegetation, and fish and wildlife populations. Significant impacts are identified and directly related to specific estuarine processes. However, lack of specific research applied to estuarine questions often hindered the reviewer's ability to make quantitative statements about these impacts. Minor impacts are also noted. The guiding purpose has been to summarize a voluminous literature and provide reference to detail more appropriately expounded in other documents.

3.1.1 Component Analysis of Energy Facilities

This chapter first addresses general construction phase impacts on terrestrial and aquatic system, and then addresses operation phase impacts of specific types of energy developments. Section 3.2 considers impacts of construction in terrestrial habitats, in aquatic habitats, and in corridors which cross both types of habitats. Most energy facilities share the common construction impacts of large scale projects.

During the operation phase, most types of energy facilities produce impacts on the environment. Section 3.3 reviews operational impacts from various types of facilities and related systems. The types of energy facilities and systems considered are: 1) facilities for conversion of fuels into electricity (dams, nuclear reactors, fossil-fuel conversion systems); 2) facilities for processing of fossil-fuels (refineries, LNG/LPG processing); 3) cooling and wastewater systems; 4) fuel delivery systems and other energy related transportation and transshipment facilities (marine vessels, marine terminals, railroads, highways, electric transmission lines, pipelines); and 5) fossil-fuel extraction facilities (oil and gas wells, OCS support).

3.1.2 Construction Phase Impact Summary

3.1.2.1 Terrestrial facilities. Construction phase impacts of terrestrial facilities are generally short-term and localized, though they may be acute for the immediate area. However, the increase in construction lead times for thermal power plants is extending the construction impacts up to a decade or more.

The most serious impacts to the estuary relate to draining and filling development sites and dredging. Dredging for water intake, effluent systems, and associated marine facilities, together with runoff and erosion from the construction site, increases turbidity. Facilities in sensitive biological communities or affecting the habitat of rare species may have highly significant long-term impacts, but in general the impacts of construction are not expected to present irremediable conflicts with fish and wildlife.

3.1.2.2 Aquatic facilities. Construction in aquatic environments produces a short-term, often severe surge of downstream sediment, reducing water quality as turbitity is elevated, damaging fish and aquatic microorganisms, and increasing depositional effects to benthic organisms. Considering the generally small size of hydro projects which may be built and the magnitude of existing impacts, such as river channel dredging and runoff from Mt. St. Helens, the contribution from new energy development will be relatively minor in the estuary.

In tributaries, however, the effects of aquatic construction may be significant. Inundation and sedimentation of productive spawning beds by small hydro projects in lower Columbia River tributaries threaten the last remaining natural salmonid populations of the basin below Bonneville Dam.

Pipeline crossings may similarly threaten spawning areas. Underwater blasting, if required, may be lethal to species within range of the shock wave.

3.1.2.3 Corridors. Impacts of corridors derive primarily from clearing ROW's and constructing transportation facilities within a long, narrow swath. The severity of impacts is highly dependent on the type and sensitivity of habitats crossed, so route selection is of ultimate concern. ROW's through old growth forests, wetlands, and riparian habitats may be particularly damaging. Typically, when forest communities in the Northwest are cleared, some soil erosion occurs, and secondary succession sets in fairly rapidly.

The impacts of transmission line construction on physical resources, particularly those associated with access road construction, are moderate and largely consist of localized erosion, sedimentation, soil compaction, and modified microclimates.

Kitchings et al. (1974), Thompson (1977), and Galvin and Cupit (1979) have reviewed impacts on vegetation and wildlife associated with the construction of transmission lines. Direct effects include vegetation removal or modification, wildlife habitat loss or alteration, soil compaction due to the use of heavy equipment, and mortality and temporary disturbance of wildlife. Indirect effects include erosion and subsequent sedimentation, community successional shifts, hydrological changes and accidental spills of toxic materials at construction sites.

Many of the impacts attributable to the construction and operation of transmission line corridors also apply to pipelines. There are, however, some differences since pipeline construction typically requires excavation and results in more soil disturbance than transmission line construction. Also, pipeline stream crossings often require the laying of pipes in the streambed and can result in serious disruption of downstream communities.

3.1.3 Operation Phase Impact Summary by Type of Energy Facility

3.1.3.1 Hydroelectric dams. Because no hydroelectric dams will be constructed in the estuary and because the Columbia River has already been intensively developed for hydroelectric power, impacts of new hydro developments are limited to downstream effects, most of which are minor in proportion to existing impacts. Small changes in the downstream flow regime, water quality, water temperature, and geohydraulic characteristics in the estuary may be traceable to installation of new peak capacity at upper Columbia River dams and development of small hydro resources on tributaries downstream of Bonneville Dam. Water temperature increases are cumulative among projects, and there already exists a significant "thermal block" to migrating salmonids during late summer.

3.1.3.2 Nuclear power plant. Only one nuclear generating plant presently operates in the study area (Trojan), and if a second plant is constructed (very low probability), it would most likely be built at the same site. The Trojan Nuclear Power Plant is sited on impermeable basalt bedrock. Thermal and chemical releases to the river from the cooling water blowdown are strictly regulated and are individually unlikely to have a significant effect on water quality. As noted above, water temperature effects are cumulative and have already caused a thermal block. Radioactivity emitted from the facility should be minor under normal operation. Major radioactive emissions are improbable, but potentially disastrous. Radioactive materials may be concentrated in the foodchain, but the effects of chronic exposure to low doses of radiation and the paths of radionuclides through the ecosystem are largely undetermined.

3.1.3.3 Fossil-fuel combustion and conversion facilities. The operation phase of a fossil-fuel generation or conversion plant imposes more significant impacts on the environment than does the construction phase. Briefly, these impacts are: atmospheric emissions of combustion products, trace elements, and in the case of coal gasification plants, emissions of coal dust and fly-ash; thermal impacts on air and water systems; removal of water; and ongoing consumption of land for waste storage (coal systems).

During the operation phase, a supply of fuel must be maintained. If a water-borne supply route is used, maintenance dredging is required. Handling of these fuels carries a risk of spillage and environmental degradation. Dvorak et al. (1978), provide a detailed discussion of the impacts of coal fired power plants on fish, wildlife, and their habitats, and a comparison with the impacts of comparably sized oil and gas fired plants. The discussion is relevant to coal gasification plants, although quantitative and qualitative differences in residuals are noted. GAI Consultants, Inc. (1979) and Soholt et al. (1980) provide detailed discussions on handling and disposal of combustion and emission abatement wastes from coal fired plants. Lyon (1977) describes a three-year detailed monitoring effort for trace elements at and around a coal fired steam plant -- again, relevant to coal gasification. Torrey (1978) describes the health and ecological effects of these trace element emissions (from combustion, coal preparation, and waste and ash disposal) and the methods of controlling these emissions.

Aquatic ecosystems appear to be highly vulnerable to the effects of power generation using fossil-fuels. Regionally, most atmospheric emissions will enter the aquatic environment, frequently concentrating trace elements and lowering the pH. Oxides of sulfur and nitrogen emitted from fossil-fuel combustion and conversion may contribute to acid rain, with broad and serious effects upon regional waters and soils.

3.1.3.4 Refinery. Small refineries have a low to medium probability of development in the study area. They may release aquatic and atmospheric pollutants typical of fossil-fuel combustion. Waste heat will also be released. Effluents and emissions, as well as oil that may be accidentally released from the facility, may enter local waters, be deposited on soils, be taken up by plants and microorganisms, and enter the food chain. Oil spills would have acute effects both at the location of the spill and areas reached through natural dispersion. Chronic effects may occur where oil residues are incorporated into bottom sediments in tidal marshes and flats, back bays, sloughs, and other backwaters. There, oil may persist and be released in acute amounts at each new benthic disturbance. Thermal effluents may be significant when considered cumulatively.

3.1.3.5 LNG/LPG processing. Few impacts are associated with the routine operation of LNG/LPG facilities. Cool water effluents may be discharged in the process of LNG gasification, making this the only type of facility that will reduce the river temperature. The risk of explosion or fire, though low, carries a significant potential impact on surrounding communities.

3.1.3.6 Marine vessels and terminals. The operation of marine vessels and terminals requires dredging and maintenance of channels. On the water column, the primary effects of dredging are short-term increases in turbidity and releases of organic matter, which consumes oxygen and supplies nutrients to the river and estuary. The operation of major vessels within the Columbia River and Estuary will disrupt normal water column stratification through agitation by the propellers. The propwash may also increase the turbidity by stirring and suspending the bottom sediments where the channel depth is close to the draft of the vessel.

The operation of marine vessels or the transfer of fuel or crude oil presents the potential for an oil spill, through human or mechanical failure. The greater the distance a tanker must maneuver, the greater the possibility of an accident leading to a spill. LNG vessels pose greater hazards of fire and explosion.

Fugitive emissions, leachate, and stockpile runoff from fuel handling and storage facilities, or a serious accident during transshipment, are primary causes of impacts from marine terminal operations.

3.1.3.7 Rail and truck. Minimal impacts are caused by rail and truck operations. Noise, exhaust emissions, and fugitive dust may present local problems, especially where regular delivery is required (e.g., coal unit train). Runoff from impervious surfaces may cause local erosion and may carry toxic chemicals. Roadside habitat is significantly different from surrounding habitat and adds local diversity in the way of edge. Road collisions may elevate local wildlife mortality, and roadways may present a migration barrier.

3.1.3.8 Transmission line. Transmission lines in the flight path of waterfowl and other birds can cause mortalities from collision with towers and wires. For some species (swans, sandhill cranes) this may be a significant source of mortality. Electromagnetic effects, although controversial, appear likely to be relatively insignificant. Raptors are vulnerable to electrocution on distribution lines, but transmission lines are usually spaced widely enough to avoid the problem. Transmission towers may provide raptor nesting substrate and perch sites. Herbicides used in ROW maintenance can have significant adverse effects on both terrestrial and aquatic communities if not applied properly. In upland communities, a shift to an earlier seral stage in the corridor leads to a shift in associated wildlife species composition, while edge effects increase density. Transmission line corridors may provide easy access to habitat for hunters and off-road-vehicles (ORV's), increasing pressure on wildlife populations.

3.1.3.9 Pipeline. Excluding accidents, pipeline operations have little impact. Maintenance of the ROW constitutes the major impact during the operational phase and are similar to those described for transmission lines. Improper discharge of hydrostatic test fluids can introduce toxic substances to aquatic environments. The rupture of a pipeline would result in a leak of gas, oil, or coal slurry. If large, an oil spill could have the same serious effects as are described for releases from refineries or marine vessels. Pipeline leaks may also contaminate groundwater supplies. Oil residues incorporated in estuarine bottom sediments may present chronic effects in addition to the acute effects occurring at the time and locale of the initial discharge.

3.1.3.10 Oil and gas wells. Drilling for oil and gas presents hazards associated with disposal or accidental release of toxic drill fluids, brines, and muds. Emissions of hydrogen sulfide and hydrocarbons may be significant. Groundwaters may be contaminated by leaking brine, or may be drained for solvent and injection uses. Land subsidence can affect groundwaters and surface communities. Oil spills, an ever-present danger, may contaminate terrestrial communities and, if not contained, may affect aquatic communities as well.

3.1.3.11 OCS support. The primary impacts of OCS development on the estuary relate to support activities. These include construction of drill rigs, platforms, and other structures, operation of transportation networks and marine terminals, and possible pipeline transport of extracted fuels. Oil spills may occur as a result of all these activities.

3.2 CONSTRUCTION PHASE IMPACT BY TYPE OF HABITAT

3.2.1 Facilities in Terrestrial Habitats

3.2.1.1 Types of facilities and probability of location in the Columbia River Estuary. Land based energy facilities that may be constructed in the study area include: onshore facilities to support marine terminals and outer continental shelf development, electric power generation plants, refineries, LNG/LPG processing facilities, cooling towers, railways and highways related to energy developments, electric transmission lines, and pipelines. Of these, the latter three involve a set of impacts particular to corridors and are treated in Section 3.2.1.3. The rest share a somewhat homogenous set of impacts, typically associated with large construction projects on land.

OCS development, nuclear and most fossil-fuel power plants, and LNG processing facilities have a low probability of future development in the study area. LPG processing and refineries are projected to have a medium probability of development in the 1981 to 1986 timeframe, and LPG processing exhibits a medium probability of expanding to a second facility by 2006. A second fossil-fuel unit at Beaver has a high probability of being built within 1987 to 1996. A high probability exists that a marine terminal will be built (at Kalama) within five years; while a second terminal is projected at medium probability in the 1981 to 1986 period.

3.2.1.2 Significant estuarine impacts. Emerson et al. (1974) provide general environmental guidelines for evaluating and reporting the effects of nuclear power plant site preparation and facilities construction. As shown in Table 3-1, they subdivide construction into four phases (preconstruction, site work, permanent facilities work, and project closeout) and identify specific construction practices during each phase and the potential environmental impacts that may be expected. Table 3-2, also taken from Emerson et al. (1974), identifies primary pollutants resulting from these construction practices. Although these impacts were described for nuclear power plant construction, they are applicable to all energy facility construction activities within the study area.

Table 3-1. Potential environmental impacts resulting from construction practices.

Construction phase	Construction types or practices	Types and degree of potential environmental impacts
Preconstruction	Site inventory	Short-term and nominal
	Vehicular traffic	Dust, sediment, and tree injury
	Test pits	Tree root injury, sediment
	Environmental monitoring	Negligible if properly done
Site Work	Clearing and demolition	Short-term
	Clearing	Loss of protective tree, shrub, and ground covers, stripping of topsoil; increased soil erosion and sedimentation; stormwater runoff; increased stream water temperatures; modification of stream banks and channels, decline in water quality.
	Demolition	Increased dust, noise, solid wastes
	Temporary facilities	Long-term
	Shops and storage needs	Increases in surface areas impervious to water infiltration, increased water runoff, petroleum product spills and runoff
	Access roads and parking lots	Increased surface areas impervious to water infiltration, increased water runoff, generation of dust on unpaved areas
	Utility trenches and backfills	Increased visual impacts, soil erosion, sedimentation for short periods

(continued)

Table 3-1. Continued.

Construction phase	Construction types or practices	Types and degree of potential environmental impacts
	Sanitary facilities	Increased visual impacts, solid wastes
	Fences	Barriers to animal migration
	Laydown areas	Visual impacts, increased runoff
	Concrete batch plant	Increased visual impacts, disposal of wastewater, increased dust and noise
	Temporary and permanent pest control (termites, weeds, insects)	Nondegradable or slowly degradable pesticides are accumulated by plants and animals, then passed up the food chain to man. Degradable pesticides having short biological half-lives are preferred.
	Earthwork Excavation Grading Trenching Soil treatment	Long-term Stripping, soil stockpiling, and site grading; increased erosion, sedimentation, and runoff, soil compaction; increased in soil levels of potentially hazardous materials; side effects on living plants and animals, and the incorporation of decomposition products into food chain, water quality
	Site drainage Foundation drainage Dewatering Well points Stream channel	Long-term Decrease in the volume of underground water for short- and long-term periods, increased stream flow volumes and velocities, downstream damages, water quality

(continued)

Table 3-1. Continued.

Construction phase	Construction types or practices	Types and degree of potential environmental impacts
	Landscaping Temporary seeding Permanent seeding and sodding	Decreased soil erosion and overland flow of stormwater, stabilization of exposed cut and fill slopes, increased water infiltration and underground storage of water, minimum visual impacts
Permanent Facilities	Transmission lines and heavy traffic areas	Long-term
	Parking lots	Stormwater runoff, petroleum products
	Switchyard	Visual impacts, sediment, runoff
	Railroad spur line	Stormwater runoff
	Buildings	Long-term
	Warehouses	Impervious surfaces, stormwater runoff, solid wastes, spillages
	Sanitary waste treat	Odors, discharges, bacteria viruses
	Cooling towers	Visual impacts
	Related facilities	Long-term
	Reactor intake and discharge channel	Shoreline changes, bottom topography changes, fish migration, benthic fauna changes
	Water supply and treatment	Waste discharges, water quality
	Stormwater drainage	Sediment, water quality
	Wastewater treatment	Sediment, water quality, trace elements
	Dams and impoundments	Dredging, shoreline erosion
	Breakwaters, jetties, etc.	Circulation patterns in the waterway
	Fuel handling equipment	Spillages, fire, and visual impacts

(continued)

Table 3-1. Concluded.

Construction phase	Construction types or practices	Types and degree of potential environmental impacts
	Oil storage tanks, controls, and piping	Visual impacts
	Conveying systems (cranes, hoists, chutes)	Visual impacts
	Waste handling equipment (incinerators, wood chippers trash compactors)	Noise, visual impacts
	Security fencing	Long-term
	Access road	Increased runoff
	Fencing	Barriers to animal movements
Project Closeout	Removal of temporary offices and shops	Short-term
	Demoliton	Noise, solid waste, dust
	Relocation	Stormwater, runoff, traffic blockages, soil compaction
	Site restoration	Short-term
	Finish grading	Sediment, dust, soil compaction
	Topsoiling	Erosion, sediment
	Fertilizing	Nutrient runoff, water quality
	Sediment controls	Vegetation
	Preliminary start-up	Short-term
	Cleaning	Water quality, oils, phosphate and other nutrients
	Flushing	

Source: Emerson et al. (1974).

Table 3-2. Types of pollutants resulting from various construction practices.

Construction phase	Construction practice	Primary pollutants
Preconstruction	Site inventory	Dust, noise, sediment
	Environmental monitoring	Visual
	Temporary controls	Sediment spoil, nutrients, solid waste
Site work	Clearing and demolition	Dust, sediment, noise, solid wastes, wood wastes
	Temporary facilities	Gases, odors, fumes, particulates, dust, deicing chemicals, noise, petroleum products, waste water, solid wastes, aerosols, pesticides
	Earthwork	Dust, noise, sediment, debris, wood wastes, solid wastes, pesticides, particulates, bituminous products, soil conditioner chemicals
	Site drainage	Sediment
	Landscaping	Nutrients, pesticides

(continued)

Table 3-2. Concluded.

Construction phase	Construction practice	Primary pollutants
Permanent Facilities	Transmission lines and traffic areas	Sediment, dust, noise, particulates
	Buildings	Solid wastes
	Related facilities	Sediment, trace elements, noise, caustic chemical wastes, sediment spoil, flocculants, particulates, fumes, solid wastes
	Security fencing and roadway	Sediments, wood wastes
Project Closeout	Removal of temporary offices	Noise, dust, solid wastes
	Site restoration	Sediment, dust
	Preliminary start-up	Nutrients, petroleum products

Source: Emerson et al. 1974.

The following discussion briefly expands the tables prepared by Emerson et al. (1974) and is organized by elements of the environment affected: air, water, land, soils, vegetation, and fish and wildlife.

3.2.1.2.1 Air. Air impacts during construction include: 1) emissions from the combustion engines of construction equipment, the vehicles bringing workers to and from the site, and the vehicles delivering construction supplies (trucks, trains, vessels, etc.); 2) dust from earthmoving activities and vehicular traffic over temporary roads; and 3) increased noise levels from vehicular traffic and construction machinery.

Emissions are related to the amount of construction activity (a function of the project size) and the number of miles workers must travel to and from the work site. Air pollutant emissions can be calculated using the current edition of the U.S. Environmental Protection Agency (USEPA) document "Compilation of Air Pollutant Emission Factors (AP-42)" (USEPA 1977) and all pertinent supplements to date. Tables 3-3 and 3-4 present the emissions from diesel and gasoline powered construction equipment which may contribute to the deterioration of local air quality.

There are similarities in the noise sources and patterns of operation which permit grouping of these sources into a limited number of categories. Table 3-5 presents construction equipment noise ranges in dBA at 50 feet for various types of equipment. Impact equipment such as pile drivers and rock drills, produce the highest noise levels. Construction on bedrock may even require blasting, with related blast shock and noise.

3.2.1.2.2 Water. During the construction of the water dependent components of a generating facility, certain aquatic impacts may occur. Water dependent components include terminals for vessel unloading, water intake, discharge structures, and effluent pipelines. Construction of these components involves dredging, excavation, and shoreline alterations, which can result in brief, localized increases in downstream sediment loads. Bay unloading areas also require additional dredging to accommodate tanker vessels. Land clearing, grading, pipe trenching, and other upland construction will result in erosion and additional siltation of aquatic environments. At the Trojan Nuclear Power Plant site, the shoreline was restored and landscaped, and such practice would typify other large construction projects. Dredging and excavation within the river itself for emplacement of pipelines and other structures increases turbidity at, and down-current from, the site. The Columbia River in the study area experiences a tidally driven reversal of flow which is also influenced by daily and seasonal variations in the water release rate at Bonneville Dam. Hence, the current direction may at times be upstream.

Compared to the ongoing maintenance dredging of the navigation channel in the Columbia River, the one-time dredging requirement for the intake, discharge, and effluent pipelines of even a large facility such as the Trojan Nuclear Power Plant is relatively insignificant, except during periods of increased and sensitive biological processes (e.g., salmon migration).

Table 3-3. Air pollutants (grams per hour) produced by diesel-powered construction equipment.

Source	Pollutant					
	Carbon monoxide	Exhaust hydrocarbons	Nitrogen oxides	Aldehydes	Sulfur oxides	Particulate
Tracklaying tractor	175	50	665	12	62	51
Wheeled tractor	973	67	451	14	41	62
Wheeled dozer	335	106	2,290	30	158	75
Scraper	660	284	2,820	65	210	184
Motor grader	98	25	478	6	40	28
Wheeled loader	251	85	1,090	19	83	78
Tracklaying loader	73	15	265	4	34	26
Off-highway truck	610	198	3,460	51	206	116
Roller	84	25	474	7	31	23
Miscellaneous	188	71	2,040	14	65	63

Source: USEPA 1977.

Table 3-4. Air pollutants (grams per hour) produced by gasoline-powered construction equipment.

Pollutant	Source				
	Wheeled tractor	Motor grader	Wheeled loader	Roller	Miscellaneous
Carbon monoxide	4,320	5,490	7,060	6,080	7,720
Exhaust hydrocarbons	164	186	241	277	254
Evaporative hydrocarbons	31	30	30	28	25
Crankcase hydrocarbons	33	37	48	56	51
Nitrogen oxides	195	145	235	164	187
Aldehydes	8	9	10	8	9
Sulfur oxides	7	8	11	8	11
Particulate	11	9	14	12	12

Source: USEPA 1977.

Table 3-5. Average noise levels in dBA at 50 feet for construction equipment.

Equipment	Noise level (dBA)
Earth-moving equipment	
Front loader	79
Backhoes	85
Dozers	80
Scrapers	88
Tractors	80
Graders	85
Truck	91
Paver	89
Material handling equipment	
Concrete mixer	85
Concrete pump	82
Crane	83
Derrick	88
Stationery equipment	
Pumps	76
Generators	78
Compressors	81
Impact equipment	
Pile drivers	101
Jackhammers	88
Rock drills	98
Pneumatic tools	86
Other equipment	
Saws	78
Vibrators	76

Source: Bolt, Beranek, and Newman 1971.

3.2.1.2.3 Land. Direct, irreversible impacts to land occur in every construction project, as acreage is withdrawn to accommodate structures and support facilities. Tables 3-6, 3-7, and 3-8 illustrate representative land requirements for nuclear power plants, oil refineries, and fossil fuel power plants.

OCS support requires construction of platform fabrication yards, supply bases, storage facilities, and marine terminals. The requirements of fabrication yards include: 200 to 1000 acres on a navigable waterway, 15 to 30 foot water depth at piers, 200 to 350 feet of channel frontage, and bridge clearance for access to the sea (OSU Sea Grant 1978). OCS supply bases have considerably less impact than platform fabrication yards, because land area requirements are less and existing port facilties may be used. Onshore service bases required for OCS exploration would function as temporarily staging areas from which equipment, supplies, and personnel would be ferried by boat or helicopter to offshore rigs. These would be replaced by more permanent production services bases, occupying perhaps 25 to 50 acres with 200 feet of wharf per offshore platform serviced (OSU Sea Grant 1978).

During construction of OCS pipelines, service bases would be required for pipe storage, preparation, coating, and loading on barges. Typical requirements are 100 to 150 acres of land, 750 feet of wharf space, and 3,000 to 15,000 gallons of water per day (OSU Sea Grant 1978).

3.2.1.2.4 Soils and sediments. Construction can significantly alter the structure and function of soils. Removal of soil overburden, importation of fill, and physical, chemical, and biochemical changes attributable to bulldozing, grading, and compacting all act to alter the ability of local soils to absorb and store water and remain biologically productive.

Reduced moisture holding capacity frequently leads to wind erosion of dry, exposed soils. Heavy rains, on the other hand, increase surface erosion, gullying, etc., of nonstructured soils. Improper excavation and stockpiling can disrupt soil horizons and bury topsoil, resulting in reduced productivity (Northwest Pipeline Corporation 1976).

Soil conservation service offices at Astoria can provide data as to erodability and sensitivity of surveyed areas. Most soils adjacent to the Columbia River Estuary are alluvial, with low slopes, and do not pose severe erosion problems. USEPA (1972), Farmer and Fletcher (1976), and Heede (1978) describe methods for evaluating erosion hazard.

Undisturbed forests in the vicinity of the Columbia River estuary are known to be stable in terms of sediment movement. Fredriksen (1971) found that dust deposition represented 84 percent of the sediment output in small undisturbed forested watersheds. Extensive rooting systems, protective canopy, porous soils, and a well developed organic layer combine to deter erosion. When forested areas are disturbed, erosion may be

Table 3-6. Comparison of total site acreage, acreage required for construction and siting of temporary and permanent facilities, and transmission right-of-ways for 20 nuclear power stations.[a]

Site acreage	$\bar{x}$ = 1,425 Range = 525-4,420
Acreage required for construction and siting of temporary and permanent facilities	$\bar{x}$ = 334 Range = 30-1,011
Acreage required for transmission-line right-of-ways[b]	$\bar{x}$ = 2,344 Range = 400-12,660

Source: Dinger 1976.

[a] Excludes sites featuring reservoir cooling.

[b] Data included for those facilities which require construction of new transmission lines.

Table 3-7. Acreage allocation (percentage of total) for several oil refinery facilities

Facility	% of total acreage	Acreage	
		40,000 b/d	80,000 b/d
Tankage	38	33	67
Roads, Shops & Buildings	19	17	33
Process Unit	18	16	32
Unallocated	10	9	18
Aqueous Waste Treatment	9	8	16
Flora	4	3	7
Buffer Zone	2	2	3
Total	100	88	176

Source: Robert Brown Associates and John Graham and Co. 1974.

Table 3-8. Approximate area requirements for the construction of three 700-MW power plants--one fired by coal, one by fuel oil, and one by natural gas.

Components	Area requirements					
	Coal-fired plant		Fuel-oil fired plant		Natural gas fired plant	
	(ha)	(acres)	(ha)	(acres)	(ha)	(acres)
Fuel storage, handling	3.6	8.9	5.1	12.6	0.3	0.8
Power generation	0.8	2.0	0.6	1.6	0.6	1.5
Waste heat dispersal (Cooling towers)	6.5	16.0	6.5	16.0	6.5	16.0
Waste handling	3.1	7.6	1.3	3.2	0	0
Total	14.0	34.5	13.5	33.4	7.4	18.3
Area permanently disturbed[a]	101.0	250.0	97.0	240.0	89.0	220.0

Source: Dvorak et al. 1978.

[a] Includes roads, parking areas, switchyards, landscaping, etc., not included in the rest of the table.

accelerated, depending on the degree and type of disturbance. Slope is the most important factor influencing soil erosion (Fredriksen et al. 1973). Soil type, however, is also considered important (Paeth et al. 1971; Fredriksen 1972; Swanson and Dyrness 1975).

Further soil changes are discussed below, with regard to their effect on vegetation.

3.2.1.2.5 Vegetation. The construction phase will result in removal, injury, and environmental stress to vegetation leading to a loss in primary productivity, reversion of existing flora to an earlier successional stage, and the establishment of a man-made landscaped community.

Clearing and grubbing will eliminate endemic plants at the project site and redistribute the organic and inorganic materials, producing soils lacking normal characteristic structures. The loss of soil nutrients due to site preparation and construction activities further decreases plant productivity and may reduce the competitive ability of indigenous species. Porosity and permeability of the soil will be influenced by compaction occurring when bulldozers and other heavy equipment are used. Together these influences will affect the recolonization and landscaping at all facilities, pipelines, and transmission line ROW's.

Logging saleable timber, burning or burial of slash, disposal of overburden and soils, and erosion of soils are additional activities potentially harming terrestrial flora.

Indirect environmental impacts will result from air, water, and land pollution by construction equipment and activity. The extent to which pollutants will influence plant communities will depend on the characteristics of the vegetation at the site, the equipment used in the operation, and the prevailing meteorological and soil conditions.

Particulate emissions are directly proportional to the area of land being worked, the level of construction activity, and the silt content of the soil, but inversely proportional to the square of the moisture content in the air. During construction activity, particulate emissions approximate 1.2 tons per acre per month as projected by the USEPA (1977).

Airborne particulates and gaseous pollutants such as localized high concentrations of sulfur dioxide and hydrocarbon exhausts from construction equipment have been shown to be damaging to plants. Anthropogenic particulates may include florides, lead, soot, magnesium, iron oxides, dust, and sulfuric acid aerosols. Nonanthropogenic particulates include calcium, aluminum, and silicon-containing soil dust. Section 3.3.1.3 treats the effects of the combustion emissions in greater detail.

3.2.1.2.6 Fish and Wildlife. Waterfront construction will result in shoreline modification and river bottom alteration. Specifically, the construction of intake and discharge structures, effluent pipelines, and marine terminal facilities to support either the construction or the eventual operation of the specific energy facility will modify adjacent and downstream aquatic habitats. Upstream impacts may also occur since tidal reversal of flow occurs in much of the study area.

Land clearing, grading, pipe trenching, and other construction activities will result in erosion and additive siltation of the river and will lead to short-term increases in downstream sediment loads. An increase in silt and turbidity can influence light penetration, temperature, and other properties of water affecting aquatic life. These effects are discussed in Section 3.2.2.

Construction activities will also affect local populations of terrestial wildlife. Clearing, excavating, grading, and filling will kill less mobile, frequently smaller, species including invertebrates, amphibians, reptiles, and small mammals. One to two foot deep ditches with steep side walls, used to bury pipes and electrical wires, may trap salamanders, frogs, and other small animals, especially during migration season. These short-term, localized mortalities should have only minor effects on otherwise healthy populations. Nevertheless, such impacts should be of concern where populations are limited and/or locally concentrated.

Large mammals and birds will migrate from construction sites and compete for food, shelter, and breeding areas with nearby populations. After being removed from their home ranges, however, scattered animals are at a disadvantage in finding food and avoiding predators and generally exhibit a decreased life expectancy. If nearby populations are at carrying capacity, competition and predation will remove the surplus animals (i.e., the weaker, younger, etc.), until numbers and composition approach premigration levels. Larger, more adaptable (i.e., tolerant of new habitat and human activity) mammals and birds may return as construction activities phase down and habitat restoration starts. Nevertheless, postconstruction populations will differ significantly in species composition, distribution, and abundance.

Cutting of old and very large trees is of particular concern because these may provide key dens for mammals and nest or roosting sites for raptors. In general, impacts to wildlife will vary by species, season, habitat type, terrain, and continued degree of disturbance.

Disturbances associated with construction activity can seriously influence animal behavior. Noise from explosives, construction machinery, and delivery trucks may scare wildlife from the site and stress others; this is particularly important during breeding season. Birds frequently abandon eggs and young, and mammals may fail to nurse successfully. The effect of noise on wildlife and other animals has been summarized by the USEPA (1971).

Temporary disturbance of wildlife during construction periods is frequently referenced in impact statements, but is poorly documented. Our literature search found little scientific documentation of this impact. In Arizona, construction activities resulted in marked and measurable wildlife community shifts and changes of animal abundance (Simono 1977), the changes being dependent on the habitat disturbed. In a Colorado study, Stahleker (1975) found reductions in breeding bird densities, particularly in arboreal habitats, related to construction activity. He also reported the abandonment of two Swainson's hawk nests due to nearby construction activities. Werschkul et al. (1976) found that logging activities in the vicinity of great blue heron rookeries reduced fledging rates, colony size, and nest density. They also found that new nesting efforts shifted away from disturbance areas. Chadwick (1974) reported mountain goats and elk left the areas where road construction and logging activities were in progress.

Equipment delivery, materials shipment, and commuter traffic to a large site, such as the two-unit nuclear plant complex at Trojan, may number 200 trucks and 1,500 personal vehicles per day (Dinger 1976). Elevated traffic volume will not only produce significant noise, but will directly lead to an increase in road kills. Game animals will most likely be subjected to increased hunting pressures due to the greater accessibility to the site and the influx of construction workers.

Obstacles to wildlife migration may be presented by new fences and canals. Chain-link fences obstruct most smaller northwest game animals and initially confuse larger species. Fences may further channel wildlife into particular routes or concentrate their numbers, making them more vulnerable to harassment and predation.

Concrete lined canals readily stop the movement of small animals and also retard the movement of larger terrestrial species causing significant mortality. Barriers are most intrusive at times of animal dispersal, such as during the colonization of new habitats by young. Barriers across traditional migratory routes may pose severe conflicts.

Biocide use may result in the accumulation of residues toxic to wildlife. The types of biocides most frequently used at construction sites are rodenticides, insecticides, and herbicides. All are used in general landscaping and vermin control.

3.2.1.3 Ecosystem perspective. Construction related impacts, in general, are short-term and localized. Large central station power plants are, however, increasingly removed from this stereotypical, short-term, acute impact scenario, as average construction lead time has lengthened over the past decade to a period of seven to twelve years.

Construction impacts may extend beyond the site boundaries, as exemplified by the development of an extensive transmission line ROW network or the accidental spillage of fuels or toxic chemicals into aquatic habitats. The effects of these activities on an ecosystem are dependent upon their magnitude, persistence, and the biological significance and resiliency of affected plant and animal species. In general, ecosystem impacts will include loss of flora and fauna, reduction in carrying capacity, destruction and modification of habitats, changes in population densities, and changes in species and habitat diversity.

The location of power plants, refineries, or other energy facilities adjacent to the river estuary, where cooling water is available, may lead to drainage and filling of wetlands and riparian habitats supporting a wide variety of birds and mammals. Loss of wetlands may also reduce the export of detritus and nutrients to adjacent estuary or riverine habitats, thereby affecting adjacent and downstream ecosystems through the food web.

Construction activities are not generally expected to adversely affect ecosystems, although local biotic communities will be destroyed or indirectly affected during site preparation and construction. Impacts to aquatic systems from increased turbidity and sedimentation may appear downstream (or upstream, depending on tidal influence) further from the site. Nevertheless, adverse impacts should decrease with increasing distance and dilution. Impacts on terrestrial systems are not expected to exhibit broad ecosystem effects.

3.2.2 Facilities in Aquatic Habitats

3.2.2.1 Types of facilities and probability of location in the Columbia River Estuary. Energy related facilities which may be placed directly in aquatic habitats include: hydroelectric dams, pipeline river-crossings, and docks and associated structures used in support of marine terminals.

No new major dams are anticipated in the study area, although a low to medium probability exists that a number of small hydro sites may be developed on lower Columbia River tributaries. A high short-term probability exists for development of at least one marine terminal in the lower Columbia River, and a medium-to-high probability exists for development of several terminals by 1996. A medium probability exists that the Oregon Natural Gas Pipeline may be upgraded by 1986.

3.2.2.2 Significant estuarine impacts. Construction of energy related facilities in aquatic habitats may lead to significant impacts, among which are turbidity and sedimentation, inundation of spawning beds, and the possibly adverse effects of pipeline crossings and marine terminals. These are discussed in the following subsections.

3.2.2.2.1 Turbidity and sedimentation. Construction in aquatic habitats can cause severe turbidity and siltation downstream (Fredriksen 1970), impacting aquatic organisms and habitats. There is little direct evidence regarding the effects of such construction on sedimentation processes in the Columbia River Estuary. Most of the sediments generated have an immediate impact on the receiving aquatic systems and eventually reach the estuary in drainages not blocked by dams. Where rivers are dammed, the time required for sediments to reach the estuary is greatly increased.

Instream and riparian construction will cause temporary increases in sediment load, can damage salmonid spawning, and affect salmon migration (Michigan Public Service Commission 1978a; Bell 1973). Poor construction practices can result in streambed and stream edge sedimentation and erosion problems. The extent and degree of impacts will be site-specific and highly dependent on timing, construction methods, mitigation, and flow conditions during construction.

Site-specific characteristics are necessary to predict sedimentation, turbidity, or streambed disturbance. Characteristics of particular importance are sediment type, stream morphology, water velocity, and discharge rates. The impacts of increased turbidity, bedloads, and sedimentation are reviewed by Bell (1973) and Crow et al. (1976).

Fairly large concentrations of suspended materials (500 to 1,000 ppm) for short periods of time are not usually detrimental to fish; however, some studies indicate salmonids will not migrate when suspended materials exceed 4,000 ppm. Prolonged exposure to some types of suspended materials will, in most species, result in thickening of the respiratory epithelium (so-called club gills) and fusion of gill lamellae, thereby interfering with respiration. Gill irritation to salmonid juveniles held in turbid waters may cause infections by fungi and bacteria. The catch of fish, and presumably their feeding, is affected at turbidity levels above 30 Jackson Turbidity Units (JTU).

The effect of bedload movement is not well defined by any measurements, partially because it is very difficult to measure. However, increased bedloads are thought to be a more serious problem than suspended sediments as they can 1) affect buried eggs and alevins by denying water exchange, 2) act as a physical barrier to young, and 3) smother food organisms (Meehan et al. 1977).

Several studies reviewed by Bell (1973) and Alley et al. (1977) report a drastic reduction of benthic fauna downstream of construction sites and major sediment sources. However, other studies reviewed by Meehan et al. (1977), indicate no change in abundance, but a shift in species composition, reducing the available food base for fish.

3.2.2.2.2 Spawning beds. Small dams on the lower Columbia River tributaries, such as the Grays, Kalama, and Lewis rivers and the Big Creek, pose a unique threat to the remaining salmon and steelhead fisheries. Spawning runs which reach these lower tributaries are the last viable natural run Chinook, coho, or steelhead on the river (Fish and Wildlife Committee 1979; Columbia River Fisheries Commission 1980). Although small hydro sites tend to be run-of-the-river, inundation of these spawning beds is possible, and flooding or construction of dams in productive beds would present an impact unusually severe in proportion to the size of the project.

3.2.2.2.3 Pipeline crossings. Stream, river, and estuary pipeline crossings pose threats to fish and other aquatic organisms similar to those described above. Streambed disturbance and subsequent turbidity and sedimentation are more likely to occur. Chinook and coho salmon and steelhead are again the species of concern most likely to be affected by pipelines crossing streams. Crossings through or above spawning areas are of particular concern. The significance of the impact would depend on the stream characteristics and the crossing technique used.

Stream bank disturbance at river crossings is a key concern, as banks are particularly susceptible to erosional processes and can destabilize riparian areas (Northwest Pipeline Corporation 1980). Disturbance of riparian vegetation can also be significant. Typical pipeline crossings of smaller rivers will disturb approximately an acre on each side, while larger river crossings will disturb an estimated eight acres on each side (Northwest Pipeline Corporation 1980).

Pipeline construction often requires blasting because of the occurrence of surficial bedrock along a selected route. Blasting in aquatic communities is of particular concern because detonation can kill nearby aquatic fauna (Bell 1973). Lethal range is a function of charge size and shock wave velocity. Slow velocity charges (e.g., black powder) have a reduced lethal range. Sensitivity to blasting varies between species. Generally, fish with air bladders are more sensitive than those without them (Kerns and Boyd 1964). Underwater seismic pressure waves have been recorded to kill fish by rupturing air bladders (Alpin 1947; Fitch and Young 1948) and, on occasion, have killed diving birds and California sea lions (Fitch and Young 1948).

Salmonid eggs in gravel are especially sensitive to shock waves. Shock waves originating on land and transmitted to water may have detrimental effects on the embryological development of salmon eggs, which pass through a vibration-sensitive period between fertilization and 30 to 40 days of age (Olson 1974).

Accidental spills of fuels, lubricants, and other contaminants used in pipeline construction can affect water quality. Temporary disruptions of river flow during aquatic construction may be required and can have significant effects on downstream biota.

3.2.2.2.4 Marine terminal. Excavation and dredging for a marine terminal results in a physical change in river and channel configuration and formerly the existing benthic habitat. In some cases, emplacement of bulkheads, rip-rap, or fill will lead to further substrate changes. Effects of dredging and dredged material disposal on soils and sediments are covered in detail in Section 3.3.4.1. The loss of shallow areas along the shore can increase local predation to migrating salmonids.

3.2.2.3 Ecosystem perspective. Ecosystem effects of aquatic construction are generally short-term, but can be significant. The common primary path of impact is through increased sediments to downstream aquatic communities. Sedimentary impacts can be severe during the construction surge, but are relatively minor in comparison to ongoing contributions from river channel dredging and the erratic Mt. St. Helens eruptions.

During dam construction and reservoir filling, river flow will be altered. Flow alterations can cause changes in temperatures, kill benthic invertebrates, and reduce secondary productivity. Stranding of juvenile salmonids and other fish is also a potential problem caused by sudden reduction in flows.

Small dam construction on the lower Columbia River tributaries has the potential to reduce the last viable natural-run anadromous fishery in the tributaries.

3.2.3 Corridors Crossing Terrestrial and Aquatic Habitats

3.2.3.1 Types of corridors and probability of location in the Columbia River Estuary. Three types of transportation corridors are required to support various types of energy related facilities: rail and roadways, transmission lines, and pipelines.

Major rail and roadways serve the Columbia River Estuary; therefore, large scale new corridors are not expected. Short spurs are expected to be required to connect existing roads and railways to new energy development facilities. The modernization and adaptation of existing lines (such as the revamping of the rail lines to handle 100 car-unit trains of coal), and resurfacing and/or widening of highways, will probably be the primary activity. Support activity will be most significant during construction, when barging and berthing facilities are not yet operational and the only method of access and delivery to the site is via land. Truck and rail will be necessary to deliver heavy construction equipment, plant machinery, and building materials.

New transmission line corridors associated with thermal power plants are not anticipated, as these are most likely to be sited, if at all, in conjunction with existing plants at Trojan and Beaver, where existing corridors may be expanded. New small hydro projects may require new transmission corridors, but no other facilities will specifically generate the need for them. Additionally, the existing transmission grid may be upgraded in the study area by 2006; a slightly higher probability exists for such upgrading on the Oregon side.

Pipelines may be built in association with OCS development, refineries, or LNG and LPG processing facilities. Piping of coal slurry to marine terminals for export or to provide fuel to a fossil-fuel thermal plant is also a possibility.

3.2.3.2 Significant estuarine impacts. Corridor related impacts derive mainly from clearing of ROW's for laying roads, pipelines, and transmission lines. These impacts are summarized below by the elements of the environment affected (air, water, land, soils and sediments, vegetation, and fish and wildlife).

3.2.3.2.1 Air. Few significant impacts on air resources have been documented from ROW clearing. No studies which specifically address the impacts of ROW's on microclimate were found. However, Heisler and Herrington (1973), after reviewing literature and research in forestry, agriculture, wildlife management, and basic metereological and physical principles, concluded that the clearing of ROW's in forested communities will alter microclimate and possibly stream temperatures.

Besides affecting the microclimate, burning, which is frequently used as a method of eliminating unwanted slash and brush during ROW clearing, can influence air quality. Geomet (1978) reports estimated fuel generation per clearcut acre for Oregon and Washington at 39.8 tons and 31.9 tons, respectively. General impacts of slash burning on air quality are reviewed by Cramer (1974) and Geomet (1978). Impacts to fish and wildlife are expected to be minor. Improperly managed slash burning has the potential for causing wildfires, but is prohibited during fire-danger periods.

Air pollution from road or railway construction will depend on site-specific characteristics, project size, construction activities, and machinery to be used. Of particular importance to highway construction is the proportion of main, secondary, and primitive roads to be built. Road type determines construction equipment and length of use, which will determine the quantity of exhaust fumes and particulates associated with construction. Local concentrations of vapors and particulates may reduce air quality for short durations, but are not expected to generate long-term impacts.

Noise levels anticipated for construction activities were provided in Table 3-5. The construction noise would be short-term, but occurs along an extensive route. Sensitive species along such corridors would be disturbed, particularly during breeding periods. Dust impacts would be minor and occur only in late summer or early fall. Impacts of dust are reviewed in Section 3.2.1.2.1.

3.2.3.2.2 Water. Highway and railway grades along the Columbia River are gradual. Riverbed gravels provide substrate material for road construction, thus there is a potential for altering local surface flows and affecting water quality. Sedimentation caused by erosion during construction, near-river site preparation, or channelization, may silt downriver streambeds and fill navigational channels, sloughs, and irrigation ditches. Failure to quickly revegetate steep, unstable, or exposed slopes may exacerbate erosion and water quality deterioration. Effects of sedimentation are discussed in Section 3.2.2.

There is little direct documentation regarding the impacts of pipeline or transmission corridor construction on hydrology and water quality. Some hydrological effects can be inferred from the clearcutting impact literature (see Section 4.2.5.3 CPCR). ROW clearing, however, unlike clearcutting, typically affects only a small portion of a watershed. Consequently, the hydrologic impacts associated with logging and road construction should be proportionally reduced. For example, an increase in water runoff during, and shortly following, construction can be anticipated, but is usually insignificant in itself. Nevertheless, additional clearing in an already heavily logged watershed may further degrade an altered hydrologic regime. Additional impacts relate to groundwater hydrology and stream crossings and are discussed in Section 3.2.2. Trench excavation, the laying of pipeline, and subsequent filling and compaction can have long-term effects on local subsurface drainage. Related, localized impacts on vegetation and wetlands are documented by the Michigan Public Service Commission (1978a). Increased ponding uphill of the line is the most typical effect.

3.2.3.2.3 *Land.* Corridors are characteristically long and narrow; therefore, impacts of construction relate directly to the number of linear miles of new clearing that may be required to serve energy facilities. The width of highway and transmission line ROW is largely determined by the size of the facility. Transmission line ROW widths depend on line voltage, as shown in Table 3-9. Pipeline ROW's are typcially about 50 to 100 ft (30 meters) wide, but may vary depending on the number of lines.

3.2.3.2.4 *Soils and Sediments.* There is little direct evidence regarding the effect of ROW construction on erosional processes in the vicinity of the estuary. However, an extensive literature has been developed on the impacts of clearcutting and affiliated road construction which is applicable to ROW impact projection.

Useful literature reviews are provided by Fredriksen et al. (1973), Gibbons and Salo (1973), USEPA (1972), Moring (1975), Crow et al. (1976), and Coats (1978). In summary, erosion, principally due to road construction, has often increased appreciably following disturbance and has degraded nearby aquatic communities. These effects, however, are variable and can be mitigated (see Chapter 7). Details on construction effects on soils

Table 3-9. Line voltages, ROW widths (feet), and required acreage per mile of line

Line voltage	Typical ROW widths (feet)	Approximate acres/mile
115/138 (AC)	90 - 150	11.0 - 18.2
230 (AC)	100 - 150	12.1 - 18.2
345 (AC)	150 - 170	18.2 - 20.6
500 (AC)	135 - 200	16.4 - 24.2
765 (AC)	260 - 280	31.5 - 34.0
±400 (DC)	140 - 150	17.0 - 18.2

Source: Galvin et al. 1979.

and sedimentation effects on aquatic systems are presented in Sections 3.2.1 and 3.2.2, respectively.

On highways and railways, the immediate placement of overburden, gravels, and impervious materials will reduce these impacts. Nevertheless, erosion on adjacent ROW's and cut banks may pose serious problems.

Several researchers provide examples of sediment generation following disturbance in the Northwest Coastal region. Brown and Krygier (1971) reported a two-to three-fold increase in sediment yield following clear-cutting and road construction in a small Oregon coast watershed. This was largely thought to be due to road construction. Fredriksen (1970) found a 100-fold increase in sediment yield following patch cut and road construction in a small steep watershed. Increases in sediment generation were measured over a nine year period. Fredriksen et al. (1976) found sediment yields of 126 kg/ha in an undisturbed small watershed, 628 kg/ha in a cut but unroaded watershed, and 5,000 kg/ha in a roaded and cut small watershed. Increased sediment yields were reported over a 15-year period.

Pipeline construction may exacerbate these effects. Due to the required excavation, considerable surface area will be laid bare and become susceptible to erosion. Settling can also occur along the pipeline and form a conduit for water flow and potential erosion. Soils with high shrink-swell potential (volume change as a function of moisture potential) may place serious lateral and vertical stresses on the pipeline. Unstable areas prone to soil creep, land slides, and other forms of mass wasting may pose similar problems.

Soil compaction from ROW construction should be similar to that from clearcutting, which has been well studied (Dyrness 1965; Froelich 1977). Soil compaction associated with the logging activities and access road construction affects soil moisture, soil temperature, soil nutrition, soil strength, and runoff (American Society of Agriculture Engineers 1971). Farmers in New York complained of reduced productivity beneath transmission lines due to soil compaction (Busby et al. 1974).

3.2.3.2.5 Vegetation. Removal or alteration of vegetation would result as trees are cleared from ROW's. Methods of clearing for transmission lines are reviewed by Galvin et al. (1979). The clearcutting method is the most common for the study area. Useable timber is harvested, while slash and shrubs are typically burned.

Revegetation in cleared areas is rapid, and disturbed sites are typically revegetated with early sere cover within one year. Land committed to ROW's is not removed from biological productivity. Disturbed sites may seed naturally with early successional annuals and biennials. Revegetation in riparian and wetland habitats, however, will proceed through natural colonization by hydrophytes from remnant and surrounding populations if substrate characteristics have not been fundamentally altered.

The use of oil to reduce wind erosion is a common construction practice and is the primary method used to reduce fugitive dusts on primitive roads. Runoff containing these surface oils are harmful to plants.

3.2.3.2.6 Fish and wildlife. The potential losses of fish and wildlife habitat are proportional to the affected areas. ROW's through old growth forests may be particularly damaging because of the long-term (centuries) required for return to its original conditions (see CPCR Vol. 2, Section 3.2.4.1).

Although railroads and highways border the estuary along most of its length, several sections remain relatively road free and undeveloped. If the location of new energy facilities requires transportation corridors to these areas, fish and wildlife habitats will be affected. In general, the expected impacts are similar to those predicted for site preparation of any energy related facility and are described in Section 3.2.1.

Herbicides which are commonly used along powerline ROW's include Tordon 101 (picloram), Weedone 170 (2, 4-D), and Ammate X or X-N1 (ammonium sulfate). If these are not used carefully, hazards to wildlife may result.

Blasting associated with roadbed and pipeline bed preparation may startle terrestrial birds and mammals, potentially leading to nest desertion and, hence, increased predation (Shaw 1970; MacInnes and Mishra 1972; Gallop et al. 1974). The long range effects, however, remain undetermined.

3.2.3.3 Ecosystem perspective. Construction of energy transportation corridors may produce severe but largely transient effects on ecosystems. Several community types may be cleared, and microclimates, soil, and moisture conditions are altered along a narrow but continuous swath. Basic ecological processes such as primary and secondary production can be temporarily affected, and ongoing community successional sequences may be altered.

Changes in community and ecosystem processes associated with successional changes are described in Section 3.2.4.1 in Volume 2 of the CPCR for the Western Hemlock Zone. Similar effects can be anticipated in the Sitka Spruce Zone, although different species of flora and invertebrate fauna are implicated.

ROW routing or poor construction techniques can seriously impact important scarce habitats, such as wetlands and riparian areas, either directly by physical destruction (i.e., filling, excavating, compacting, clearing) or indirectly by sedimentation, root destruction, and alteration of hydrology. The severity of the impacts are highly dependent on site-specific conditions; hence, route selection is a major concern.

Due to the large amounts of soil disturbed during the trenching operation, erosion potential is most severe for pipeline construction. Additionally, trenching in the streambed and the stockpiling of highly erodable materials in riparian areas can cause dramatic temporary increases of sediment loads and may cause mortality to disturbed riverine benthic communities. Such impacts would be most severe in the boulder-cobble zone and gravel beach zone as defined by Bauer (1974) (see CPCR, Conceptual Model, Section 2.5.4 for the definition of these zones and for curves of erosion and deposition).

3.3 OPERATIONAL IMPACTS BY ENERGY FACILITY

3.3.1 Electric Conversion Facilities

3.3.1.1 Hydroelectric facilities. Both the Columbia River and its principal tributaries in the study area (Lewis and Cowlitz rivers) have been developed for hydroelectric power. No new major dams in or near the study area are anticipated; however, a low-to-medium probability exists for the development of a number of micro, small, and medium hydro sites, ranging from less than one to 36 MW, on undeveloped Columbia River tributaries and as additions to existing dams.

3.3.1.1.1 Significant estuarine impacts. Existing dams on the Columbia River and its tributaries exert cumulative effects on the estuary which are very great in proportion to the incremental impacts potentially presented by new projects. Changes in downstream flow regime, water temperature, water quality, and geohydraulic characteristics may be traceable to such development. Placement of small dams on lower Columbia tributaries poses a severe conflict with the last viable natural-run spawning salmonids in the river, which depend on these lower reach spawning grounds. Such development may occur on the Grays, Lewis, and Kalama rivers and on Big Creek. Smaller tributaries may also attract small hydro projects, but additional sites are not yet identified.

Downstream flow. Construction of hydroelectric projects alters the flow of rivers, but this is no longer a critical consideration for the Columbia River because the flow is already highly regulated by existing dams. The natural flow of a stream is greatly altered when a dam is built and the water discharge is managed for electrical power and flood control (Simmons 1974). Flows below a dam have fewer or smaller peaks, and turbidity is usually decreased. Figure 3.1 summarizes the generalized effect of reservoir operations on the flow regime of the Columbia River at the Dalles Dam, Oregon. As indicated, spring and summer peak flows have been reduced to increase storage, and winter flows increased to meet electricity demands. This altered flow regime is established to meet power demands. Flows, however, are manageable, and in some cases hydropower dams can be used to improve summer flow conditions of downstream areas (Fish and Wildlife Committee 1979). There are ten multipurpose projects in the upper basin that have been managed to enhance tributary and mainstream flows for the benefit of specific fisheries (Columbia River Fisheries Council 1980).

An aspect of altered flow that is not indicated in Figure 3.1 is the effect of daily peaking which increases the short-term changes in water levels downstream. This effect on the study area is controlled by the

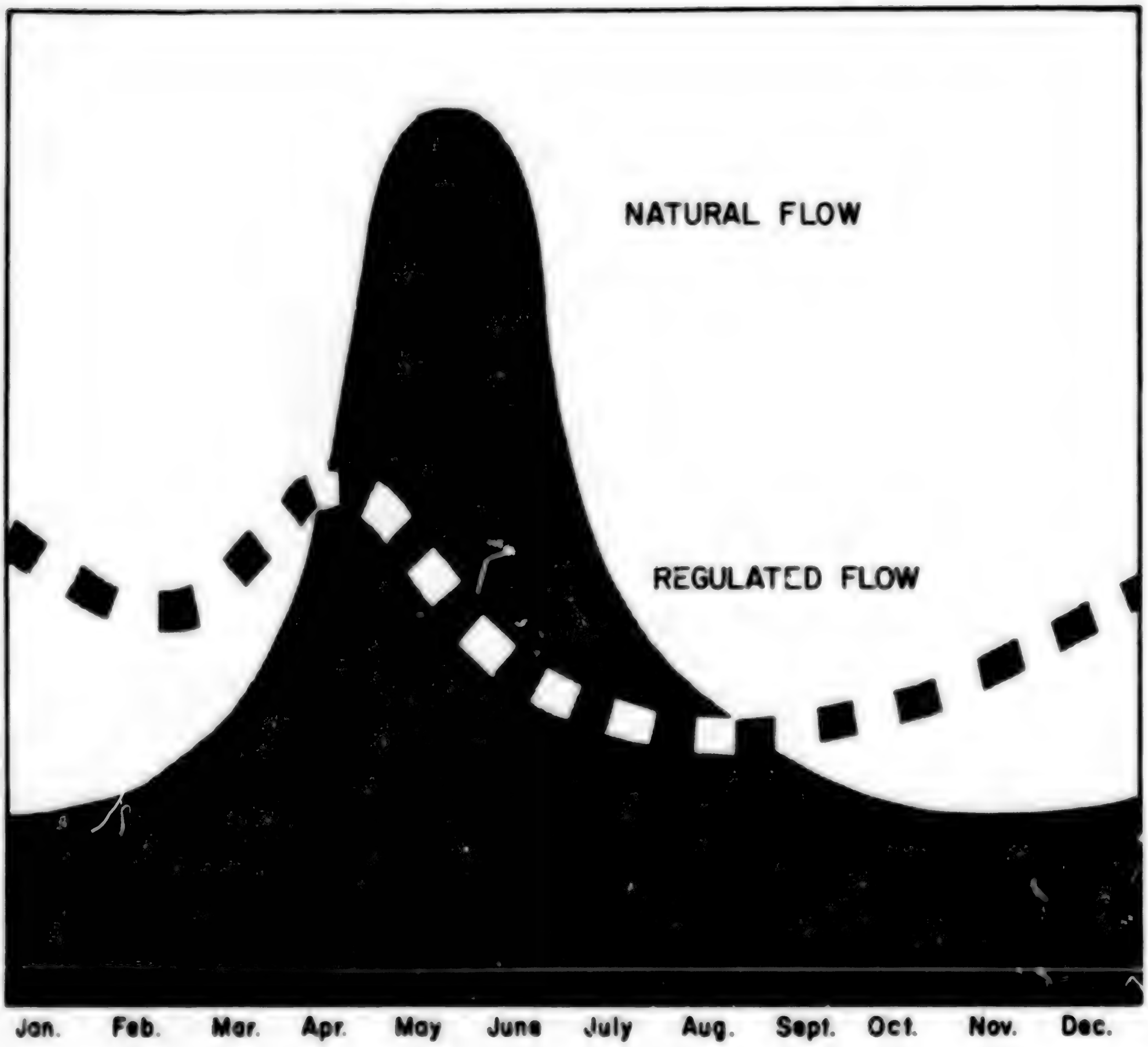

Figure 3.1. Cumulative effect of several dams on the flow regime of the Columbia River.

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coordinated operation of all Columbia River dams, culminating in the operation of Bonneville Dam, which regulates releases from upriver dams. Bonneville's hydraulic capacity, plus available pondage, is usually sufficent to contain and reshape river flow fluctuations delivered from upstream dams, even considering the substantial additions to hydro peak capacity planned over the next decades (Blightner, U.S. Army Corps of Engineers; pers. comm.). Even if a spill were necessary, river fluctuations would be largely flattened out as far upstream as Longview, and, considering tidal flows, would probably be scarcely noticeable in the estuary (Baldrica, BPA; pers. comm.).

Downstream water level fluctuations related to power peaking have an adverse effect on riparian vegetation. For example, Odum (1972) reports that decreased flooding due to reservoir projects reduces the productivity of downstream riparian communities. Decreased flooding has been demonstrated over the past fifty years through the operation of existing Columbia River dams.

Reservoir and downstream water level fluctuations can also cause adverse effects on riparian and wetland wildlife communities. This can result from degradation of riparian vegetation communities, flooding of waterfowl nesting sites or furbearer dens, and increased predator access to normally unreachable wetlands and islands.

Hazards connected with dams are associated with containment failure. Although dams reduce downstream flood hazards by regulating the flow, if for some reason the dam fails, the resulting flood may be more severe than the natural hazard. For example, a worst case scenario for the estuary might involve the failure of Bonneville Dam. The water released would inundate all downstream riparian and estuarine habitats. The increased flow would scour bottom sediments, and as the flow receded, riverine and lacustrine sediments would be deposited in the river and the estuary, obliterating the existing benthic community. The scour and deposition from such a flood would destroy much of the riparian and estuarine habitats.

Downstream temperature. Water temperature is an important limiting factor for anadromous fish. The effects of reservoirs on water temperature is well documented (USEPA 1971; Simmons 1974; Rounsefell 1975). The cumulative effect in the Columbia Basin has been to generally increase temperatures in the entire river system (Moore 1968) and to delay the temperature peaks by one month (USEPA 1971). Because summer flows have been increased by the operation of the hydro system, summer temperature extremes may have been beneficially moderated by the system. Additional storage projects and powerhouses have come on line since the publication of these data, and additional thermal impacts are probable. Some reservoirs can reduce downstream temperatures if the drawoffs come from below the thermocline (Simmons 1974).

The effect of new impoundments would most likely be to further increase water temperatures of the basin. Other thermal loads due to withdrawals for irrigation and small thermal discharges from energy developments will continue to increase the temperature of the river system and the estuary.

The downriver aquatic community can be drastically altered by temperature and flow effects imposed by a hydroelectric dam (Alley et al. 1977). For example, where late summer temperatures are cooled by outfalls from deep reservoirs, cool water fish can be favored and native warm water fish displaced. In other cases, warm water fish may be favored. Considering the moderating effect of tidal flows, the temperature effect in the estuary itself may be insignificant; however, at Bonneville Dam, elevated river temperatures (above 70°F) may constitute a thermal block to migrating anadromous fish (USEPA 1971).

Downstream water quality. Reservoirs alter water quality, including such parameters as dissolved gases, sediments, and nutrients (Simmons 1974; Rounsffell 1975; Fish and Wildlife Committee 1979). Where reservoirs are chemostratified, outfalls below the cline would alter the normal dissolved oxygen levels and other chemical properties downstream. Many reservoirs act as sediment and nutrient traps blocking the transport of important nutrients to downstream communities (Simmons 1974). This effect has not been particularly serious in the Columbia River system or the estuary.

Geohydraulic effects. Some dams silt-in, depending on sediment loads and design. Some of these are periodically flushed out with deleterious effects on downstream water quality (Simmons 1974). The lower Columbia River and dams in the watershed of Mt. St. Helens are subjected to unpredicted siltation when the volcano erupts.

Rapid fluctuation in downstream flows has, under some conditions, caused bank instability and erosion (Burns 1972). Flow modifications can also alter substrate mix (riffle:pool) proportions in downstream areas (Alley et al. 1977; Keller 1977). Curtis (1959) reports that a 90 percent reduction in stream flow caused average width, depth, and velocity to decrease by 22, 44, and 75 percent, respectively. Similar flow decreases resulted in a 75 percent decrease in riffles, 53 percent increase in shallow runs, and 96 percent decrease in deep, fast runs (Kraft 1972).

Reduction of winter or spring peak flow reduces the ability of the fluvial system to form deep pools and renew gravel beds, thereby diminishing fish habitat diversity and carrying capacity (Alley et al. 1977; Keller 1977). Daily fluctuations in flows due to peaking demands are thought to have a potentially disruptive effect on social hierarchy of fish, since the territory and food supply is frequently altered (Alley et al. 1977). The nature and importance of such geohydraulic changes in the estuary itself would depend upon the interaction of oceanographic and riverine factors which were beyond the scope of this study. In any event, the effect, if any, will continue to be dominated by the existing dams.

3.3.1.1.2 Ecosystem perspective. New hydroelectric development will affect the Columbia River Estuary ecosystem, primarily, by altering the physical conditions for estuarine life. Water temperature, water quality, flow rates and fluctuations, deposition or erosion of sediments, and the building up or wearing away of bentnic and riverine topographic features affect the parameters to which living organisms must adjust. Aquatic communities are most immediately affected by changes in these parameters; however, effects are anticipated to be small in relation to those exerted by existing dams.

3.3.1.1.4 Reservoir impacts. The impacts of dam construction and reservoir operation occurring upstream of the estuary are not directly within the scope of this study. The principal downstream effects may include erosion and severe turbidity during dam construction (Paeth et al. 1971; Fredriksen 1972; Fredriksen et al. 1973; Swanson and Dyrness 1975). Methods for erosion prediction are summarized by Smith and Wischmeir (1960), Falletti (1976), and Farmer and Fletcher (1976).

Vegetation communities inundated during the filling of the reservoir are lost and replaced by a phytoplankton based lacustrine community. Inundation or clearing of den sites, caves, roost trees, and snag trees can result in significant impacts to wildlife if these habitat features are limiting to the population (Thomas et al. 1979). Because reservoirs are placed in river valleys, they frequently inundate important big game wintering areas (Fry, Pacific Gas and Electric; pers. comm.). Additionally, migration routes for big game and riparian-dependent species can be barred or disrupted.

Wild run anadromous fish populations of the Columbia River have been severely reduced due to the effects of dams. General effects have been reviewed by Rounsffell (1975), the Fish and Wildlife Committee (1979), and Columbia River Fisheries Council (1980).

3.3.1.2 Nuclear reactors. Presently there is only one nuclear power plant (the Trojan Plant at river mile 72.5 on the Oregon side) within the study area, and there is a very low probability of another being built at the same site by 2006 (see Section 2.2.3.2).

3.3.1.2.1 Significant estuarine impacts. The primary environmental issue of concern with regard to the operation of a nuclear reactor in the study area relates to the release and disposal of radioactive material. Thermal effluents are treated in Section 3.3.3.

Radioactive waste products include spent fuel with its fission byproducts and unused uranium, irradiated fuel cladding, and the ionized particles produced within the primary coolant by exposure to neutrons and gamma rays emitted in the fission process. The nuclear fuel cycle involves reprocessing of the spent fuel to recover the unused portions, as well as storage of the high and low-level waste products.

High level wastes include the long-lived transuranics (elements heavier than uranium) and fission fragments contained within the spent nuclear fuel rods. No permanent method of storing these materials has, as yet, been proven effective. The question of permanent storage involves national, political, and technical issues beyond the scope of this report.

Radioactive isotopes may be present in either the atmosphere or the aquatic discharges from a nuclear power plant. Row (1976) describes the sources of radioactive wastes from boiling water reactors (BWR) and pressurized water reactors (PWR). The Trojan Plant is a PWR. Table 3-10 presents the estimated liquid releases of radionuclides and the resultant concentrations in the Columbia River (PGE 1972) for the Trojan plant.

Airborne radioactive material is primarily released from the cooling tower. The physical dimensions of the cooling tower alter wind direction, speed, and turbulence factors which determine dissipation and concentration of radionuclides released to the air. Aquatic discharges are generated by cooling water blowdown (Section 3.3.3 discusses the origin and nature of blowdown). The chemicals added to the water in the cooling loops, as biocides and to prevent corrosion and scaling, are released to the environment from the condenser or the cooling tower, and are subjected to ionizing radiation in the primary loop.

Once in the environment, radioactive material may enter the hydrological or soil biogeochemical cycles; accumulate in terrestrial plants through either dry or wet deposition of airborne material and uptake via surface and irrigation water; and enter the food chain, concentrating in higher trophic levels. In the Columbia River ecosystem, the concentration, distribution, and bioenvironmental effects of radionuclides released from nuclear reactions at Hanford, mostly in the 1960's, are described in several studies edited by Pruter and Alverson (1972).

Absorption of radionuclides by aquatic organisms is related to water temperature, river storage, and trophic level. Renfro (1972) found that, in the aquatic food chain, organisms concentrating zinc-65 in the lower trophic levels had the shortest ecological half-life, with each succeeding trophic level showing a longer half-life. Ecological half-life measures the time required to reduce radionuclide specific activity by one half in the organism through both radioactive decay and biological mechanisms, in consideration of continued uptake of the radionuclide through the food web.

Tritiated water (water bearing an isotope of hydrogen having two neutrons in addition to the normal proton) may be of concern because of the large volume released from power plants; however, it exhibits a short half-life, a low disintegration energy (solely by Beta emission), and a low specific activity. It is also uniformly distributed in bodies, (i.e., not concentrated in any specific organs), and exhibits virtually no food chain concentration.

Existing information suggests that most of the radionuclides released are chemically inert noble gases which do not enter into atmospheric and/or terrestrial pathways. The general phytotoxicity of low doses of radionuclides remains undetermined, especially since plant reactions are highly dependent on specific environmental conditions and genetic characteristics. Two principal exposure pathways for wildlife are by external radiation, due to noble gas releases, and by magnification of environmental concentration

Table 3-10. Estimated liquid releases of radionuclides from the Trojan Plant and concentrations in plant dilution water and Columbia River water.

Nuclide	MPC 10 CFR 20 (Ci/cc)	Release rate (Ci/yr)	Average yearly[a] concentration in discharge (Ci/cc)	Fraction of MPC	Average yearly[b] concentration in river (Ci/cc)
H-3	3.0×10^{-3}	7.0×10^{2}	4.2×10^{-5}	1.4×0^{-2}	3.5×10^{-9}
Cr-51	2.0×10^{-3}	1.5×10^{-3}	8.7×10^{-11}	4.3×10^{-8}	7.2×10^{-15}
Mn-54	1.0×10^{-4}	1.3×10^{-3}	7.5×10^{-11}	7.5×10^{-7}	6.3×10^{-15}
Mn-56	1.0×10^{-4}	4.7×10^{-3}	2.7×10^{-1}	2.7×10^{-6}	2.3×10^{-14}
Co-58	1.0×10^{-4}	3.9×10^{-2}	2.3×10^{-9}	2.3×10^{-5}	1.9×10^{-13}
Fe-59	6.0×10^{-5}	1.7×10^{-3}	9.8×10^{-11}	1.6×10^{-6}	8.2×10^{-15}
Co-60	5.0×10^{-5}	1.2×10^{-3}	6.9×10^{-11}	1.4×10^{-6}	5.8×10^{-15}
Sr-89	3.0×10^{-6}	1.9×10^{-4}	1.1×10^{-11}	3.7×10^{-6}	9.1×10^{-16}
Sr-90	3.0×10^{-7}	5.6×10^{-5}	3.2×10^{-12}	1.1×10^{-5}	2.7×10^{-16}
Y-90	2.0×10^{-15}	5.1×10^{-5}	2.9×10^{-12}	1.5×10^{-7}	2.5×10^{-16}
Sr-91	5.0×10^{-5}	2.8×10^{-4}	1.6×10^{-11}	3.2×10^{-7}	1.3×10^{-15}
Y-91	3.0×10^{-5}	3.2×10^{3}	1.8×10^{-10}	6.2×10^{-6}	1.5×10^{-14}
Mo-99	2.0×10^{-4}	1.2×10^{0}	6.9×10^{-8}	3.5×10^{-4}	$5.8 \times 1\text{-}^{-12}$
I-131	3.0×10^{-7}	1.0×10^{0}	5.8×10^{-8}	1.9×10^{-1}	4.8×10^{-12}
I-132	8.0×10^{-6}	3.7×10^{-2}	2.1×10^{-9}	2.7×10^{-4}	1.8×10^{-13}
Te-132	3.0×10^{-5}	9.4×10^{-2}	5.4×10^{-9}	1.8×10^{-4}	4.5×10^{-13}
I-133	1.0×10^{-6}	8.8×10^{-1}	5.1×10^{-8}	5.1×10^{-2}	4.2×10^{-12}
Cs-134	9.0×10^{-6}	1.2×10^{-1}	6.9×10^{-9}	7.7×10^{-4}	5.8×10^{-13}
I-135	4.0×10^{-6}	2.3×10^{-1}	1.3×10^{-8}	3.3×10^{-3}	1.1×10^{-12}
Cs-136	9.0×10^{-5}	1.8×10^{-2}	1.0×10^{-9}	1.2×10^{-5}	8.7×10^{-14}
Cs-137	2.0×10^{-5}	7.7×10^{-1}	4.4×10^{-8}	2.2×10^{-3}	3.7×10^{-14}
Ba-140	3.0×10^{-5}	1.9×10^{-3}	1.1×10^{-10}	3.7×10^{-6}	9.1×10^{-15}
La-140	2.0×10^{-5}	4.3×10^{-3}	2.5×10^{-10}	1.2×10^{-5}	2.1×10^{-14}
Ce-144	1.0×10^{-5}	3.0×10^{-4}	1.7×10^{-11}	1.7×10^{-6}	1.4×10^{-15}
Total		7.2×10^{2}	4.2×10^{-5}	2.6×10^{-1}	3.5×10^{-9}
Total excluding H-3		4.4×10^{0}	2.5×10^{-7}	2.5×10^{-1}	2.1×10^{-11}

Source: PGE 1972.

[a] Average dilution flow = 8700 gpm.
[b] Average river flow = 230,000 cfs.

through the food chain. External doses of radiation to terrestrial animals from contact with airborne radionuclides are normally minor. Insignificant increments of radiation occur from exposure to materials deposited on the ground surface (Battelle 1975). Radionuclides enter animals primarily through food and water, inhalation being of secondary importance. Deer and other grazers that eat large amounts of vegetation may be most vulnerable to concentration of radionuclides by ingestion.

Iodine-131 enters the food chain from the air, passing through vegetation to herbivores which may concentrate it in their milk, flesh, and particularly in the thyroid gland, where it is associated with both somatic and carcinogenic effects.

Other radioactive isotopes may also enter the food chain. For example, carbon (146) may be incorporated in plants during photosynthesis because carbon is an essential element for living organisms and is involved in most biological processes. Bird studies at the Savannah River Plant indicated that juveniles and adults have different patterns of radiocesium uptake (Straney et al. 1975). Isaev and Pokarzheveskii (1979) found that ^{90}Sr influences sexual maturation and aging in field mice in artificially contaminated plots.

The environmental and biological pathways of radiation are generally not well understood, nor are the cumulative effects over several generations. Aspects such as sublethal effects and the relation between cancer and genetic diseases also remain undetermined.

3.3.1.2.2 Ecosystem perspective. The greatest ecosystem related concerns of a nuclear reactor operation is a major radioactive release. Events that could lead to a release of radioactive materials include mechanical failure, human error, accident, sabotage, earthquakes, and possibly war.

Hakonson (1975) reviewed the environmental pathways of plutonium through terrestrial plants and animals. He concluded that plutonium reaches native plants and animals through a combination of physical and biological processes which were not quantitatively defined. He found that plutonium appears not to be concentrated along terrestrial food webs, although it is concentrated in marine food webs.

Potential effects on biological communities of serious radiation leakage from power facilities may be extrapolated from Woodwell's (1967) studies of radiation in the Northeast field and forest communities. Woodwell (1967) demonstrated that prostrate, depressed, and decumbent plants and plants with a few small chromosomes are better able to survive high radiation. Under high radiation doses, forests were replaced by low growing shrubs, which in turn were replaced by heath sedges, which finally were replaced by mosses and lichens. The early successional communities exhibited greater plasticity and tended to be more resilient to radiation, a trend strikingly similar to that observed from other perturbations such as fire.

Available information over the last 10 years for existing nuclear facilities indicates significant radiation exposure has not occurred. Nevertheless, because the phytotoxicity of low doses of radioactivity remains undetermined in plants and animals, especially with respect to their reactions in biochemical cycling and physiological processes, long-term impacts on the ecosystem and biosphere may still occur, although these are unknown.

3.3.1.3 Fossil-fuel combustion and conversion facilities. The Beaver Generating Plant at Port Westward is the only fossil-fuel plant in the study area. It burns No. 2 fuel oil, but is expected to be converted to a primarily natural gas operation. A high probability exists that an additional unit will be developed at Beaver within the 1987 to 1996 period, and a medium probability exists that such a unit may burn synthetic fuel produced by coal gasification at Port Westward.

3.3.1.3.1 Significant estuarine impacts. Fossil-fuel combustion and conversion produces solid waste, liquid effluents, atmospheric emissions, and waste heat. Impacts from cooling tower and related wastewater facilities are discussed in Section 3.3.3. No coal fired power plants are projected for the study area, so the impacts of such facilities are not discussed. A coal gasification facility near the gas fired generating plant at Port Westward is the primary coal related development of ecological consequence. Coal gasification frequently requires at least partial combustion of coal feedstock (for example, the Lurgi process, discussed below), but the process is controlled in a manner that produces quantitatively and qualitatively different types and concentrations of emissions than coal fired power plants. Natural gas or fuel oil may be used to fire generation facilities in the study area.

Atmospheric emissions. Atmospheric emissions from combustion of fossil-fuels are presented in Table 3-11 for gas and oil, for comparable units of heat input. SO_x production is greatest from oil, negligible from gas, and varies for different types of oil. NO_x production is comparable for both. Particulate emissions are insignificant for oil and gas.

Although coal gasification is not as clean as oil or natural gas combustion, it is important to realize that oil fuels require refining before they can be used. Considerable quantities of SO_x, NO_x, and hydrocarbon vapors are released to the atmosphere in the refining process. Additional quantities of hydrocarbons are also released in the handling of crude and fuel oils and in the initial extraction of crude oil.

Coal characteristics are variable and directly affect the volume and nature of environmental residuals. In this analysis, it is assumed that Western, subbituminous coal strip-mined in Montana or Wyoming provides feedstock for gasification. This coal is typically low in sulfur (less than 1.0% as received), ash (less than 10% as received), and caloric value

Table 3-11. Atmospheric emissions from combustion in oil and natural gas fired fossil-fuel electric power facilities[a].

Emission product	Products released (lb/10^6 Btu)	
	Fuel oil[b]	Natural gas[c]
Particulates	0.06	0.015
Carbon monoxide	0.02	0.017
Sulfur dioxide	3.81	0.0006
Sulfur trioxide	0.05	--
Nitrogen oxides	0.73	0.6
Hydrocarbons	0.01	0.001
Aldehydes	0.007	--

[a] Data derived from Dvorak et al. (1978) and represent emission products in the absence of pollution abatement equipment. A hyphen indicates data not provided.

[b] Assumed heat content = 18,000 Btu/lb, 8 lb oil/gal oil, sulfur content = 3.5%

[c] Assumed 1000 Btu/ft^3

[d] Assumed 14,000 Btu/lb (30.8 x 10^6 Btu/MT), 5% ash, sulfur content = 1%

(7,000 to 9,000 Btu/lb). Coal mined near Gillette, Wyoming supplies the Boardman plant operated by PGE, and has the following characteristics:

Moisture	32.5 %
Ash	7.0 %
Volatile matter	32.5 %
Fixed carbon	31.0 %
Sulfur	0.48 %
Caloric value	8,025 Btu/lb

Coal reserves are typically secured on long-term contract, and coal similar to that described above would most likely be obtained by PGE for gasification at Beaver.

The design and operating parameters of the gasification process employed further influences residuals released to the environment. Among the most significant variables are the gas quality (low, intermediate, or high-Btu gasification process), source of heat (direct or indirect), source of hydrogen (steam or pure gas), and source of oxygen (air or pure gas). A number of gasification processes, both pilot and commercially tested, are available, and each renders a different mix of emissions and effluents based on specific process steps. Table 3-12 contrasts the residuals of several gasification processes. Other principal pollutants of concern include NH_3, HCN, H_2S, and phenols. The Lurgi process is in several significant respects the cleanest of those reviewed. Oxides of sulfur (particularly for intermediate-Btu gasification) and particulates are

Table 3-12. Summary of gasification residuals for western coal (Tons/10^{12} Btu coal input).

Type of gasification process	Particulates	NO_x	SO_x	HC	CO	Solids
High-Btu gasification						
HYGAS	5.7	68.3	5.9	1.2	3.8	3,730
BI-GAS	3.4	58.3	14.1	0.9	3.1	3,840
Synthane	13.0	115.0	9.6	1.9	6.4	3,830
Lurgi	2.1	76.9	5.6	1.3	4.3	3,730
CO_2 accepter	3.3	38.1	61.7	0.6	2.0	8,610
Low- to intermediate-Btu gasification						
BuMines (atmospheric)	0	0	12	0	0	3,460
BuMines (pressurized)	0	0	14.1	0	0	3,460
Koppers-Totzek	5.4	5.2	17.6	5.5	3.7	3,460
Lurgi	0	0	3.6	0	0	3,460

Source: Hittman Associates (1975).

greatly reduced. A materials balance for a high-Btu gas Lurgi plant using western coal to produce 250 million cubic feet per day is presented in Table 3-13. The reader is cautioned that coal gasification technology is rapidly evolving, and much information is not widely known or is unavailable, due to proprietary restrictions. An assessment of the relative environmental impacts of gasification processes must be made on the basis of current literature and manufacturer's specifications at the time a development is proposed, and should not rely on this or any other general review.

All gasification processes require some preparation of the coal feedstock, including (as a minimum) handling for storage and recovery, breaking, and sizing; further pretreatment may be required. Coal handling and coal processing releases considerable quantities of coal dust, but this can be minimized by dust control measures described in Chapter 9.

Coal contains an assortment of trace elements, some of which are radioactive. Through combustion, these elements may be released to the atmosphere and enter the ecosystems. They may escape in vapor form or as particulate matter, or may be concentrated in the bottom ash (see Table 3-14). Some elements emitted in fly ash, such as cadmium, chromium, manganese, mercury, arsenic, beryllium, fluorine, and lead, are more concentrated among the smaller particles emitted (Torrey 1978). These fine particles are of concern because they easily escape particulate collectors and are more apt to be inhaled by animals. Uranium and thorium occur naturally in coal and vary in connection with the origin and type of coal.

Table 3-13. Materials balance for high-Btu gas, 250 million cubic feet per day, Lurgi plant using western coal.

Input		Output	
Coal	23,600 tpd	Solid waste	1548 tpd
Water	9.3×10^6 gpd	Air emission	37.3 tpd
		NH_3	112 tpd
		S	116 tpd
		Tar	4090 Btu/d
		Naphtha	32,665 gpd

Source: Hittman Associates (1975).

Table 3-14. Groups of elements and their tendencies for distribution in coal combustion residues.

Group	Distribution tendencies	Elements					
I	Concentrated approximately equally in bottom ash and fly ash	Al	Ce	Fe	La	Rb	Sm
		Th	Ba	Co	Hf	Mg	Sc
		Sr	Ti	Ca	Eu	K	Mn
		Si	Ta				
II	Preferentially contained in the fly ash	As	Ga	Sb	Cd	Mo	S
		Cu	Pb	Zn			
III	Tending to be discharged to the atmosphere as vapors	Hg	Cl	Br			

Source: Ray and Parker 1977.

Table 3-15 presents maximum short-term ground level concentrations of SO_x, NO_x, and particulates from a 100 MW power plant burning Western coal. Although coal generation is not projected for the Columbia River Estuary, the table illustrates the type and magnitude of ambient concentrations which may impact local fish and wildlife from coal gasification or oil or gas generation facilities. A comparably sized facility fired by natural gas would emit comparable quantities of NO_x, but insignificant amounts of SO_2 or particulates. A comparably sized fuel oil fired plant, on the other hand, would be insignificant in particulate production, comparable in NO_x emissions, and greater in SO_2 discharge. Coal gasification would likely produce somewhat lower SO_x and particulate emission.

Effluent to aquatic systems. Blowdown from the cooling system is discussed in Section 3.3.3. Coal pretreatment may produce a waste stream carrying suspended and dissolved solids and acids. Researchers at the University of Oklahoma (1975) report that for every trillion (10^{12}) Btu's produced, 84.4 to 937.0 tons of suspended solids, 42.8 to 66.0 tons of dissolved solids, and 4.4 to 70.7 tons of acids are also produced.

Solid waste. Coal gasification produces a significant volume of ash. As shown in Table 3-12, most processes produce 3400-3800 tons per 10^{12} Btu coal. Due to the volume of spent dolomite used for sulfur recovery, the CO_2 Accepter process produces as much as 8610 tons for a comparable input.

Assuming a common pile height of 30 feet, the solid wastes require several hundred acres for disposal. The ash disposal pile may be revegetated to control erosion and runoff, but a several year lag will be unavoidable. During this lag time, ditches and settling ponds or containment may be required to prevent contamination.

Solids may also be generated in the pretreatment process; about 4,000 tons per 10^{12} Btu input are reported by Hittman Associates (1975). For a 250 million cubic feet per day gasification plant and associated 500 tph washing plant, the combined ash and pretreatment waste products may equal the daily refuse production of a city of one million.

Effects of emissions on living organisms. Coal related impacts are thoroughly covered by Dvorak et al. (1978). Releases of gases, particulates, and trace elements to the atmosphere, water, and soil ultimately leads to an interaction with plant and animal life. Dust from coal piles and handling operations, and particulates from combustion, may settle on vegetation, lower photosynthetic productivity, plug the stomata of the leaves, and cause leaf necrosis. High concentrations of most pollutants are known to cause acute damage to tissues, whereas smaller concentrations result in growth reduction attributable to interference with plant enzymes (American Chemical Society 1968). Impacts vary depending on light, humidity, temperatures, soil characteristics, and plant form. Responses of plants to air pollutants have been summarized by the American Chemical Society (1968), Mudd and Kozlowski (1975), and Duffus (1980).

Under meteorological conditions that create maximum ground level concentrations of gaseous emissions, impacts on vegetation may be either

Table 3-15. Maximum short-term ground level concentrations of SO_2, particulates, and NO_x from a 100 MW plant using western coal.[a]

Distance to maximum (m)	Sampling time[b]	SO_2 (g/m^3)	Particulates (g/m^3)[c]	NO_x (g/m^3)
600	3 hrs.	967	24	316
	24 hrs.	267	7	92

Source: Dvorak et al. 1978.

[a] Assumes no scrubber for Western coal
[b] Data from Turner (1969) for 3-hour sampling time; data from Montgomery and Coleman (1975) for 24-hour sampling time
[c] Assumes 99.5% efficiency for precipitators

chronic or acute. USEPA (1977) developed dose-response curves for plants of varying sensitivity to SO_2. These curves and related plant lists, grouped by sensitivity, are presented in Appendix C of Dvorak et al. (1978).

The uptake of sulfur dioxide by plants at a greater rate than it can be oxidized and assimilated results in sulfite poisoning characterized by chlorophyll destruction and cell collapse (Treshow 1970). Sulfur dioxide tolerances for woody trees, shrubs, herbaceous plants, and weeds, as well as crop and ornamental plants, are summarized by Dvorak et al. (1978).

Trace elements released in either particulates or vapor may also impact vegetation. Appendix D to Dvorak et al. (1978) describes the behavior of selected trace elements which have been found to have toxic effects on some terrestrial plants.

Impacts of sulfur and nitrogen oxide gaseous emissions on animals are primarily inferred from toxicological studies on laboratory animals and epidemiological studies of human populations. Results indicate that the effects of these gaseous pollutants are most pronounced on the respiratory system. Dvorak et al. (1978) note that the maximum three-hour concentration of SO_2 predicted for model generating plants is one-sixth of the lower levels at which deleterious effects have been demonstrated in laboratory animals receiving acute exposures. In summarizing the effects of sulfur oxides on animals, Dvorak et al. (1978) said:

> "Extrapolation of these data to wildlife in the vicinity of an SO_2 source is compounded by the variability of results in the toxicological studies, variability of sensitivity of individual

> species to SO_2, duration of exposure, concentrations of emissions from the power plant, and the accuracy of laboratory animals as models for wildlife. Sulfur oxides may affect wildlife more indirectly than directly, because impacts upon vegetation may lead to habitat modification or loss of important foods."

Dvorak et al. (1978) also noted that extrapolation of data on NO_2 concentrations to wildlife in the vicinity of generating stations is also uncertain, but that maximum levels predicted from models appear to be below levels required to affect animals in the laboratory.

The effects of trace elements on wildlife are difficult to evaluate due to the large number of variables and the lack of specific information relating elements to wildlife impacts. Dvorak et al. (1978) summarize these information gaps.

Acute sulfur dioxide concentration affects mainly the respiratory system of animals. A concentration of 1.6 ppm will cause reversible bronchial constrictions; detectable respiratory effects increase above this level (Duffus 1980). Below 25 ppm, irritant effects occur mainly in the upper respiratory tract and eyes. In many cases air emissions may not be produced in quantities which are lethal, or clearly harmful, but may subsequently alter factors of resistance to stress, disease, and death.

The vapors of oil may not only be flammable but also toxic, irritating, anathetic, or a combination thereof (Halvorsen 1979). Crude oils in particular contain many gases that may be injurious or fatal if inhaled. Sour crudes contain hydrogen sulfide gas whose toxic properties parallel those of hydrogen cyanide gas.

Newman (1980) summarizes the major biological systems of animals affected by selected air emissions (Table 3-16), and the abnormal behavior exhibited by birds and mammals to these emissions (Table 3-17). Table 3-18 documents responses of birds and mammals to acute versus chronic exposures.

Acid rain. The gaseous emissions of sulfur and nitrogen compounds are chemically converted in the atmosphere to form sulfuric acid and nitrous and nitric acids, which contribute to the acidity of regional rainfall. Acid rainfall, which lowers the pH (increases the acidity) of aquatic systems, is not yet a serious regional problem in the Pacific Northwest; however, there has been a tremendous regional input of SO_2 to the atmosphere from Mt. St. Helens.

Acid rain has already contributed to the acidification of lakes and streams on a large scale in eastern Canada and northeastern United States (Fritz 1980). Acidification of aquatic ecosystems is dependent on the natural buffering capacity of those lakes and streams which receive the acid rains, and the combined regional emissions of SO_x and NO_x from all combustion sources and natural sources. Rainfall pH monitored at the University of Washington in Seattle has ranged from 3.9 to 5.2, 70 percent of the time, and some alpine lakes in Washington are now below 5.0 (Welch and Chamberlain 1981).

Table 3-16. The major organs, systems, and structures of animals affected by selected air emissions.

Pollutants	Eyes	Central nervous system	Circulatory system	Gastro-intestinal system	Hepatic system	Pulmonary system	Respiratory system	Renal system	Skeletal & dental structure
Asbestos	-	-	-	-	-	X	-	-	-
Arsenic	-	-	-	X	-	-	X	-	-
Barium	-	X	-	-	-	X	-	-	-
Beryllium	-	-	-	-	-	-	X	-	X
Boron	-	X	-	-	X	-	X	-	-
Cadmium	-	-	X	-	X	X	-	X	-
Carbon monoxide	-	X	-	-	-	-	-	-	-
Chromium	-	-	-	X	-	-	X	-	-
Fluoride	-	-	-	-	-	-	-	X	X
Hydrocarbons	X	-	-	-	-	-	X	-	-
Hydrochloric acid	X	-	-	-	-	-	X	-	-
Hydrogen sulfide	-	X	-	X	-	-	X	-	-
Iron	-	-	-	-	-	-	X	-	-
Lead	-	X	-	X	-	-	-	-	-
Manganese	-	X	-	-	-	X	-	-	-
Mercury	-	-	-	X	X	-	X	X	-
Molybdenum	-	-	-	X	-	-	-	-	-
Nickel	-	-	-	-	-	X	-	-	-
Nitrogen dioxide	-	X	-	-	-	X	-	-	-
Particulates[a]	-	-	-	-	-	-	X	-	-
Phosphorus	-	-	-	-	-	-	X	X	-
Photochem. oxid.	X	-	-	-	-	X	X	-	-
Selenium	-	X	-	X	-	-	-	-	-
Sulfur dioxide	X	-	-	-	-	-	X	-	-
Vanadium	-	-	X	-	-	X	X	-	-
Zinc	-	-	-	X	-	-	-	-	-

Source: Newman (1975).

[a] Particulates refer to unidentified pollutants.

Table 3-17. Some of the effects of air pollutants on the behavior of domestic or caged animals.

Selected air emissions	Observed abnormal behavior
Arsenic	Incoordination of gait, muscular paralysis
Barium	Incoordination of movements, twitching, tremors, muscular paralysis
Beryllium	Temporary lethargy in dogs
Boron	Incoordination, tremors, listlessness, coma
Carbon Monoxide	Incoordination of gait and movements, reduced appetite in chickens, impairment of learned activities in rats
Chromium	Stiffness, loss of appetite
Fluoride	Lameness, stiffness, weakness
Hydrocarbons	Dizziness, fatigue, loss of appetite
Hydrogen sulfide	Lethargy, gasping
Lead	Bellowing, roaring, staggering about with rolling eyes, frothing of mouth, grinding of teeth, ataxia, maniacal excitement, lethargy, loss of appetite, delirium
Manganese	Lethargy, tremors
Mercury	Incoordination of movements, paralysis, anorexia, lethargy, blindness
Molybdenum	Stiffness in legs and back
Phosphorus	Restlessness, nervousness
Selenium	Abnormal movement and posture, fear, nervousness, opisthotonus

Source: Newman 1975.

Table 3-18. Negative responses (X) of domestic or caged birds and mammals exposed to 25 air pollutants.[a]

Responses	Air pollutants																									
	Arsenic	Asbestos	Barium	Beryllium	Boron	Cadmium	Carbon Monoxide	Chromium	Fluoride	Hydrocarbons	Hydrochloric Acid	Hydrogen Sulfide	Iron	Lead	Manganese	Mercury	Molybdenum	Nickel	Nitrogen Dioxide	Particulates[b]	Phosphorus	Photochem. Oxid.	Selenium	Sulfur Dioxide	Vanadium	Zinc
Changes in population numbers	X	X	-	-	-	X	-	-	X	-	-	X	-	-	-	-	-	-	X	X	-	X	-	X	-	X
Changes in blood chemistry or physiology	X	-	-	X	-	X	X	-	-	-	-	X	-	X	-	-	X	X	X	X	-	X	-	X	X	-
Changes in cellular enzymes	X	-	-	X	-	-	-	-	X	X	X	-	X	-	-	-	-	-	X	X	X	X	-	X	-	X
Changes in external appearance	X	-	X	-	-	-	-	-	X	-	-	X	-	X	-	-	X	-	X	X	-	-	X	-	-	-
Changes in population distribution	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	X	-	-	-	X	-	-
Changes in death rate (in free living animals)	X	X	-	X	X	X	-	-	X	-	-	X	-	X	-	-	-	-	-	X	-	X	X	X	-	-
Changes in birth rate	X	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	X	-	-	-	-
Changes in growth rate	-	-	-	X	-	-	-	-	X	-	X	-	-	X	-	-	-	X	-	-	-	-	-	X	-	-
Changes in genetic resistance	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	X	X	-	-	-	-
Abnormal behavior	X	-	X	X	X	-	X	X	X	X	-	X	-	X	X	X	X	-	X	-	X	X	X	X	X	X
Physiological changes observed in autopsy and histological analysis	X	X	-	-	-	X	X	-	X	-	-	X	-	X	X	-	-	X	-	X	X	-	X	-	X	X
Lowered resistance to natural environmental stress	X	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	X	X	-	X	-	X	-	-
Residue accumulation in body tissues	X	X	-	X	X	X	X	X	X	-	-	X	X	X	X	X	X	-	X	X	X	-	X	-	X	X
Tetragenic, mutagenic, or carcinogenic	-	X	X	X	-	X	-	X	-	X	-	-	-	-	-	-	-	X	-	-	-	X	X	-	-	-

[a]For specific levels and duration, see Newman (1975).

[b]Particulates refer to unidentified pollutants.

Source: Newman (1975).

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Acid precipitation on vegetation may result in 1) changes in stomata size and frequency; 2) decreases in overall growth; 3) increases in bark acidity; 4) changes in the physiology of foliar organs; 5) alterations in root functions; 6) direct injury to the foliage of conifer and deciduous trees; 7) excessive adventitious budding; 8) premature abcission of mature leaves; 9) poorer germination of seeds; 10) decreased pollen germination; 11) accelerated leaching of nutrients from foliage, humus, and soil; 12) inhibition or stimulation of plant diseases; 13) inhibition of free-living nitrogen-fixing bacteria in the soil; and 14) inhibition of nodule formation in legumes. These impacts were compiled from various sources and summarized by Dvorak et al. (1978). Within aquatic systems, acid rain may have a slightly positive effect on some vegetation as elevated pH levels increase the availability of some nutrients. Alternatively, other vegetation may decline with the changing aspects of microbial decomposition.

The effects of acid rain on terrestrial animals will be minimal, unless the acid rain results in soil and vegetation modification in a habitat critical to a particular species. Aquatic animals are more vulnerable. As pH decreases, the diversity of zooplankton communities decreases. Aquatic insects, molluscs, and worms are eliminated or reduced under acidic conditions. Amphibians show reproductive impairment as a first symptom of lower pH, and as the pH is lowered more, direct toxicity occurs. Examples of other direct and indirect impacts of acid precipitation that have recently been demonstrated and examples of ecosystem effects are described by Dvorak et al. (1978), Gage (1980), Fritz (1980), and Newman (1980).

3.3.1.3.2 Ecosystem perspective. Long-term exposures to high concentrations of air and water pollutants may result in subtle changes to the ecosystem. Plant communities may gradually change as a result of continued exposure to emissions and effluents, and as concentrations build up in the soil. Changes in entire food webs could be connected with buildup in air, soil, and water. A shift in trophic structure from a predator dominated community to saprophite dominated food webs is possible. For example, air emissions may cause small changes in litter pH, which then alters the decomposer community (i.e., fungi and bacteria), thus altering the nutrient cycling capabilities of the community (Jackson and Watson 1977).

Air pollutants may produce ecosystem level effects by reducing resistance of plants to pathological agents, for example, sarufly epidemics occurring in the sulfur and nitrogen dioxide affected forests in Poland (Sierpinski 1967; Newman 1980). Bark beetle attack in Ponderosa Pine forests occurred at higher rates when trees where injured by oxidants (Wood 1973). Community changes in plants, invertebrates, and wildlife species are likely from such major reductions in dominant plants.

Precipitates of primary air pollutants, in the form of acid rain, have been shown to produce changes in soil pH and water chemistry to such a degree that aquatic and terrestrial producers have drastically declined, resulting in a subsequent loss of primary and secondary consumers (Gage 1980). In aquatic systems the growth of rooted plants and the rate of decomposition of organic matter is reduced, leading to an increase in fungi and a decrease in bacteria and aquatic invertebrates for fish to feed on.

Acid rain suppresses the decay of organic matter and affects mineral storage in soils, both of which have ecosystem ramifications.

3.3.2 Fuel Processing Facilities

3.3.2.1 Refineries. Refining industry development in the lower Columbia River and Estuary will probably be on a relatively small scale, since the existing northwest refineries in Washington should meet the regional requirements. Also, the larger tankers can not cross the entrance bar to the Columbia River or navigate within the relatively shallow dredged channels. Nevertheless, one or more small- to medium-sized refineries could be constructed in the study area within the next 25 years. If oil or natural gas is discovered in amounts feasible to exploit in the estuary or offshore, additional refinery development may be stimulated.

A refinery is probably more water dependent than a fossil-fuel plant. Delivery of crude oil to a Columbia River Estuary refinery would probably be made by ship or barge; hence, a dependency on marine transportation exists. Consequently, the construction of the refinery would also require construction of a marine terminal at the facility for offloading crude oil and onloading refined products.

3.3.2.1.1 Significant estuarine impacts. Impacts of refineries discussed in this section include those related to atmospheric emissions, thermal emissions, solid wastes, waste water, and oil spills. The latter is also discussed in terms of the specific habitats that might be affected.

Atmospheric emissions. The major air pollution sources for particulates, SO_x, CO, and NO_x within fuel oil refineries are the process heaters and boilers. Their combustion products are similar to those emitted from fossil-fuel plants. Major sources of hydrocarbon emissions include general fugitive emissions throughout the refinery, emissions from crude and petroleum products storage tanks, and emissions from tanker or barge loading/offloading processes. Combustion emissions will vary depending on the fuels used for refining. Table 3-19 presents atmospheric emissions from a 200,000 b/d fuel oil refinery using fuel oil and fuel gas produced at the refinery for the heat source. The effects of the pollutants are discussed in detail in Section 3.3.1.3.

Sittig (1978a) notes that new methods of controlling emissions can remove up to 99.9 percent of the hydrogen sulfide originally introduced to the acid gas plant, but that due to the relatively large volume of the acid gas stream, the ultimate release of SO_x to the atmosphere after treating is still substantial.

Air quality is not expected to deteriorate to the extent that it will impair healthy vegetation, but could be a problem during improper refinery operation. Emissions of most significance to flora include hydrocarbons and the oxides of sulfur and nitrogen.

The toxic effects attributable to hydrocarbons released from refineries are mainly caused by the derivatives produced by photochemical

Table 3-19. Air emissions (lb/d) from a typical 200,000 b/d crude feed fuel oil refinery.

Emission	lb/d
Particulates	6,320
SO_x	16,000
NO_x	11,830
CO	1,200
Hydrocarbons	73,970

Source: Sittig (1978a).

oxidation rather than by the primary pollutants themselves. Photochemical smog is damaging to many plants, especially sensitive conifers (Duffus 1980). Ozone, a major oxidant of hydrocarbons, influences plant metabolism and other physiological processes, producing necrosis, fluking of upper surfaces, collapse of cells, bleaching of chlorophyll, and the eventual breakdown of leaf structure (Mudd and Kozlowski 1975).

Thermal emissions. The effects of cooling towers and related waste heat produced in refinery operation are discussed in Section 3.3.3.

Solid wastes. Solid wastes generated from a 200,000 b/d fuel oil refinery are estimated at four tons per day, and for a comparable gasoline refinery, seven tons per day. These solids contain many materials appearing on the USEPA toxic substances list, and as such constitute a waste disposal problem. Detailed descriptions of types of waste solids generated, how they are generated, and how they are handled are described by Sittig (1978a).

Disposal of solids may be by land filling, with or without incineration, or by soil biodegradation. Incineration has the advantage of freedom from most odors, independence of weather conditions for disposal, and a high reduction of volume and weight. The ash remaining from the incineration is essentially inert and is suitable for landfilling.

Wastewater. Water is also used within the various refining processes. Wastewater results from the following major sources: sour water stripper condensate, contaminated process water, oily process area storm water, oily cleaning water, and oily water from ship's ballast. The combined wastewaters from a 200,000 b/d fuel oil refinery contain about 52.5 lb/d of organic material (Sittig 1978a). The combined wastewaters are collected and treated before release to the environment. Table 3-20 presents the composition and concentration of typical wastewater effluent from a refinery.

Refinery treated wastewater discharge would be subject to an NPDES permit, and effluent concentration values less than those depicted in Table 3-20 may be required by the permitting authority.

Oil spill. Refineries and petrochemical facilities import crude oil, primarily Alaskan or Arabian light, and produce motor gasoline, diesel fuel, residual fuel, and miscellaneous liquid products. Accidents at either the shipping or transfer stages of crude, the process stage, or the distribution stages of refined products could spill or leak large volumes of oil into the ecosystem.

Terrestrial accidents will most likely have localized impacts. Minor oil spills at the site would be intercepted by holding walls before contaminating terrestrial plants. Undetectable oil leaks in pipelines may be of greater concern, depending on soil characteristics, nature of surface vegetation, and presence of groundwater.

Minor aquatic oil spills at the site would be contained at the pier by booms, immediate skimming, and other cleanup activities. Nevertheless,

Table 3-20. Concentrations (ppm) of pollutants in oil refinery wastewaters (based on a 200,000 b/d crude feed, and a wastewater flow rate of 3.0×10^6 g/d).

Effluent	Concentration
BOD	15
COD	80
Ammonia	2
Hydrogen Sulfide	0.1
Total Phosphorus	2
Phenol	0.1
Oil	2
Suspended Solids	10
Dissolved Solids	370

Source: Sittig (1978a).

aquatic and shoreline habitats would deteriorate over the long-term due to the incremental effects of such spills.

Major spills may result from vessel collisions or groundings, train derailments, fires, and/or explosions. The release of a large amount of oil, possibly over large areas, could impact all levels of the food chain from phytoplankton to large mammals.

3.3.2.1.2 Habitat-specific impacts of oil pollution. The general effects of oil pollution on habitats of the Columbia River and Estuary, as described in Sutherland (1979), are summarized below.

Tidal marshes. Oil causes particularly severe problems in marshes, where it can adhere to the marsh plants and contaminate sediments. Because flushing action is subdued in these areas, oil may remain for years and effectively destroy this important primary production area. The National Research Council (1980) review of oil effects in marshes concluded that a spill would not generally cause immediate widespread damage, but most references indicate that major damage should be expected.

Tide flats. Oil spills on tide flats have long-term deleterious effects if oil becomes incorported into the sediments, killing burrowing invertebrates and depriving the many organisms that depend directly or indirectly on them for food. Major productive areas could be lost in this manner.

Open water. Oil on the open water tends to first impact those organisms which live on or near the surface. Waterfowl are the most obviously affected; however, plankton are also impacted. In turn, this influences the other organisms in the water column which feed on plankton. The heavy fractions of oil sink and affect benthic invertebrates, further deteriorating the food chain. Raptors such as the bald eagle, may feed on fouled organisms and could be harmed by ingesting oil contaminated food. Seals would also be impacted, but the effects of oil on them is unclear.

Sand beaches and beachgrass. The effects of oil on the sandy beaches are usually minimal except for the aesthetic impacts in those areas where the beaches are used recreationally.

Gravel beaches. The effects of oil are relatively insignificant.

Bays, sloughs, and backwaters. Contamination by oil can be a serious problem in bays and sloughs. Poor water circulation tends to keep the oil trapped in the area, facilitating incorporation into the food chain, and thus affecting a large variety of organisms.

Riparian and intertidal vegetation. The primary impact of oil on this habitat is indirect, mediated by organisms which must feed in contaminated water areas. The effects on these organisms could be severe and long-term, particularly for threatened species.

Petroleum products may harm living organisms in numerous ways. Direct effects include mortality caused by coating and asphyxiation, contact poisoning, poisoning from exposure to toxic water soluble compounds, and disruption of body insulation and buoyancy. Indirect effects, include reduction and contamination of food resources, habitat loss, and physiological or behavioral effects, such as reproductive failure, intoxication, or increased vulnerability to disease and predation (National Research Council 1980).

A matrix of specific effects of oil pollution in different marine and estuarine organisms is presented in Figure 3.2 which indicates the wide range of influence that may be expected from larger spills. Relationships between chronic and sublethal effects of petroleum on marine organisms were generalized by Beak Consultants, Inc. (1975). Sublethal effects occur at concentrations as low as one order of magnitude below acute toxic levels; and chronic effects, particularly those involving larval and early developmental stages, occur at concentrations as low as three orders of magnitude below acute toxic levels. The toxicity of oil to aquatic birds, in particular the small concentrations required to cause embryonic death of chicks, has been the subject of several recent symposia (Dieter 1976; Szaro 1977).

The National Research Council (1980) has reviewed the effects of oil on various animal groups. Birds are highly vulnerable to oil spilled in aquatic habitats. Oil coating reduces the insulation produced by feathers, reducing their buoyancy. The ingestion of oil while preening may directly kill birds, or interfere with feeding, leading to starvation. Little conclusive evidence exists for the effects of oil on mammals and plankton. Fish may be less vulnerable than other marine organisms because of their mobility and the protection afforded by the slimy mucous on their surfaces, but studies indicate that toxic effects may be produced both directly and through feeding on contaminated benthic organisms. According to the National Research Council (1980), intertidal organisms are relatively unaffected because of their hardiness and rapid reproduction and because oil is rapidly removed by wave action.

Recovery following a single spill may be rapid, depending on the environment in which the spill occurs and the nature of the oil, but if oil residues are incorporated into sediments, its persistent release may contaminate the system for years. The turbidity of the water determines the degree to which oil will contact and consequently become incorporated in silts and sediments. The National Research Council (1980) states that chronic low-intensity oil leaks may disrupt community succession or alter food chain balance, while never giving the ecosystem a chance to regain its original balance.

Long-term ecosystem effects may result from oil spills or chronic oil leakage. For example, oil has accumulated in subtidal sediments following spills (Blumer et al. 1973; Vandermeulen and Gordon 1976), and there is evidence that these areas often experience long-term damage (Michael 1977). Oil trapped in sediments may retain its original chemical characteristics for long periods, re-enter the active water column, and once again disperse within marine systems. This is a particular concern for sediments which will be dredged.

Organism/Habitat	Rock	Sand	Mud	Mixed/ coarse	Mixed/ fine	Eelgrass bed	Kelp bed	Salt marsh	Open water
Mammals	M: ** (otters) T: ?	M: ** (otters) T: ?	M: * (harbor seal) T: ?	M: ** (otters) T: ?	M: ** (otters) T: ?	X	M: *** (otters) T: ?	X	M: *** (otters) T: ?
Birds - Offshore feeders	M: ** (guillemots) T: *	M: * T: *	M: * (ducks, gulls) T: *	M: * T: *	M: * T: *	M: ** (brant, ducks) T: *** (brant, ducks)	M: *** T: ***	M: ** T: **	M: *** T: ***
Birds - Estuarine and shorebirds	M: ** (oystercatchers) T: ** (oystercatchers)	M: * T: **	M: * T: *	M: * T: **	M: * T: **	M: * T: **	X	M: * T: **	M: *** (phalaropes) T: * (phalaropes)
Birds - Casual marine feeders	M: ? T: ?	M: ? T: ?	M: ? T: ?	M: ? T: ?	M: ? T: ?	M: ? T: ?	X	M: ? T: ?	M: ? T: ?
Fishes - Shoreline	M: ** (tidepool) T: **	M: 0 T: **	M: 0 T: *	M: ** (tidepool) T: **	M: 0 T: **	M: * T: **	M: 0 T: **	X	M: * T: *
Fishes - Demersal	M: * T: *	M: 0 T: **	M: 0 T: *	M: * T: **	M: 0 T: **	M: * T: **	M: 0 T: *	X	M: 0 T: 0
Fishes - Open Water	X	M: ** (spawning) T: *** (spawning)	M: 0 T: * (juvenile)	M: * (juvenile) T: ** (juvenile)	M: *** (spawning) T: *** (spawning)	M: 0 T: ** (juvenile)	M: 0 T: * (juvenile)	X	M: ? (surface) T: ** (surface)
Echinoderms	M: *** (intertidal) T: ***	M: * T: *	X	M: *** (intertidal) T: ***	M: * T: *	M: * T: **	M: 0 T: **	X	M: 0 T: * (larvae)
Crustaceans	M: *** (barnacles) T: *	M: * T: *	M: * T: *	M: *** (barnacle) T: *	M: * T: **	M: * T: **	M: 0 T: *	X	M: ? T: **
Mollusca	M: *** (intertidal) T: ***	M: ** T: **	M: * T: ***	M: *** (intertidal) T: ***	M: ** T: ***	M: *** T: ***	M: 0 T: ** (abalone)	M: * (soft clam) T: * (soft clam)	M: ? T: ?
Annelids	M: ? T: **	M: ? T: **	M: * T: **	M: ? T: **	M: ? T: ***	M: ? T: **	M: ? T: *	X	M: ** T: ***
Algae	M: ** T: *	X	X	M: ** T: **	M: ** T: **	M: ** (epiphytes) T: * (epiphytes)	M: * (epiphytes) T: * (ephiphytes)	X	X
Grasses	M: ** T: ***	X	M: * T: ?	X	M: * T: ?	—	X	X	X

Legend:
M = mechanical impact potential
T = toxic impact potential
X = group rare in this habitat
* = minor impact
** = moderate impact
*** = severe impact
0 = insignificant impact
? = insufficient data
()= indicated impact applies particularly

Figure 3.2. The effects of petrochemicals on organism groups in general habitats.

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In addition to long-term ecological effects, immediate cleanup operations are not often very successful and may cause more environmental damage than the petroleum. Oil spill contingency plans suggest application of chemical dispersements such as Corexil 9527, but this agent is just as toxic to embryogenesis in birds as the crude oils (Albers 1979a,b). Furthermore, human disturbance associated with cleanup may harm wildlife. Cleaning is not recommended for beaches used by pinnipeds as haul-out areas or rookeries (Lindstedt-Siva 1979). Cleanup activities should be avoided in biologically sensitive habitats including salt marshes, rocky beaches, sandy beaches, and tidal flats because human foot traffic, substrate removal, steam and hydro cleaning, and application of chemical dispersants are each more detrimental to flora and fauna than the hazards from oil itself.

Many pesticides are soluble in oils and fats, and oil slicks have been documented to have pesticide concentrations 10,000 times greater than the surrounding environment (Vagner 1972). Incorporated into the herbivore trophic level at such high concentrations, these pesticides pose a serious threat to primary and secondary predators.

3.3.2.1.3 Ecosystem perspectives. Refineries have significant impacts which may enter ecosystem processes by a number of pathways. Emissions from combustion of fossil-fuels enter atmospheric, aquatic, and ultimately soil cycles and may have far-reaching effects on all biological communities. Of even greater significance may be the biological effects from chronic and accidental releases of crude or refined oil into the biosphere. Oil residues can enter bottom sediments in tidal marshes, flats, bays, sloughs, and backwaters, where they may persistently contaminate aquatic and, indirectly, terrestrial food chains with serious long-term consequences.

3.3.2.2 LNG/LPG processing. There is only a low probability of an LNG facility developing in the study area by 2006, and a medium probability that more than one LPG facility will be built. Associated marine terminals and/or pipelines may be constructed in support of such development.

3.3.2.2.1 Significant estuarine impacts. For either LNG or LPG, the routine operation of a facility is essentially nonpolluting. The risk of fires or explosion from a large release of LNG or LPG presents the most significant concern related to this type of energy development. This risk poses a threat to vegetation, fish, and wildlife, but it is generally evaluated in terms of risk to human life and structures. Because of this risk such facilities are often built far from population centers. The risk to humans is minimized, but the potential risk to natural resources remains.

Construction of the marine terminal for the LNG facility involves impacts particular to marine terminals, but not exclusive to LNG facilities. Construction related impacts of marine terminals are discussed in Section 3.3.5.2. Section 3.3.5.3 discusses impacts of pipelines which distribute the product from LNG facilities.

Unlike other energy facilities in which waste heat must be discharged into the environment, an LNG facility must use the environment as a source of heat in order to gasify the LNG. Instead of increasing the temperature of the river, it has the potential to decrease the temperature if river water is used as the heat source for gasification.

Fish may be harmed by the water discharged by the vaporizers of an LNG facility, or by the intake structure or water pump impellers. Cool water discharges will be slight and not harmful to fish. The chilling of the Columbia River by the vaporizers will have little effect on the river and the estuary.

The probability of a catastrophic failure of an LNG tank (either on vessel or on land) is low (OIW 1978b; Davis 1979; Moore 1979; OIW 1979). Nevertheless, vessels transporting LNG or LPG are vulnerable to accidents (collisions or groundings) while in transit to the terminal. Thus, areas potentially impacted by an LNG spill also include the portions of the estuary and river downstream from a facility. Although the probability of an accident at any particular segment of the river is low, many different ecosystems are at some risk; some of these contain critical habitats or support endangered species.

3.3.2.2.2 Ecosystem perspective. The operation of LNG/LPG facilities are relatively harmless. A cooling effluent may be discharged into the estuary from LNG gasification, but is expected to have little effect. The risk of fire or explosion is low but such a catastrophe could damage surrounding communities.

3.3.3 Cooling Water and Wastewater Facilities

During the operation of a pressurized water reactor (PWR) such as the Trojan Plant, fission of Uranium (U-235) produces fission fragments, transuranics, neutrons, high energy Gamma radiation, and heat. Waste heat is transferred through a series of closed cycles by the working fluid, culminating in a heat recovery cycle at the condenser, where steam condenses to hot water. The condensate loop is not completely closed and releases heat to the environment. At the Trojan Plant, this loop discharges waste heat through a wet cooling tower, which radiates heat to the atmosphere through evaporation. Hence, heat generation is both the useful output of a nuclear reactor and a waste product.

A fossil-fuel generating facility, like a nuclear facility, requires water for cooling purposes. Water is also used in the refining process for cooling, much as in nuclear and thermal power plants. Once-through cooling simply pumps water from the source through the plant heat exchangers, and back to the source again. Use of cooling towers can reduce the water withdrawal requirements over once-through systems by more than 90 percent. Most refineries use mechanical draft evaporation towers for cooling. These towers have baffles, called drift eliminators, to separate entrained water from the air stream, thus reducing the amount of water carried into the air. Use of wet cooling towers reduces the amount of waste heat that is discharged into aquatic systems, but because of evaporation, the consumption is greater than the discharge.

Cooling systems have a wastewater system which regularly removes corrosive dissolved solids from the circulating water. This process, called blowdown, produces an effluent stream associated with the operation of all cooling water systems.

Because of the warm temperature of the Columbia River in the late summer and early fall and the possible impacts on fish migrations, it is expected that future energy facilities will not use once-through cooling systems, but will use cooling towers instead.

3.3.3.1 Significant estuarine impacts. The impacts of cooling water and waste water facilities discussed here are those related to waste heat, blowdown and wastewater, and salt drifts.

3.3.3.1.1 Waste heat. Most energy facilities are located along the shores of a river or estuary because they depend on waterways for transportation and as a source of process water. Almost all energy facilities require cooling fluid that increases the temperature of process water. In contrast, processing of LNG requires water as a heat source to gasify the liquified natural gas. The discharge from such a facility would slightly decrease the temperature of the river.

For most such facilites, however, thermal effluents are of concern because of their potential heating effects. A discussion of the operating experience with the Trojan Plant will illustrate the scope and nature of the issues for cooling and wastewater facilities.

The Trojan Plant uses a natural draft wet cooling tower. This often results in a cloud at the top of the tower and, depending upon temperature and humidity, may result in or contribute to localized fog. An average of about 20,000 gallons of water per minute is drawn from the river. Losses of cooling water from evaporation are replaced at the rate of 11,000 gpm. To prevent buildup of chemicals within the cooling water, 8,700 gpm are returned to the river. Temperature increase in the Columbia River from the Trojan Plant cooling discharges is negligible because most of the heat is dissipated to the atmosphere (Beak Consultants Inc. 1978).

The effects of evaporation, makeup water requirements, return of blowdown water, and the heat of the returning blowdown or once-through cooling water to the river vary seasonally, based on a number of factors including air temperature, humidity, and river temperature. PGE (1972) provides further details on Trojan water and heat discharges. If another facility is built at the Trojan site, it will probably have similar water use and heat discharge characteristics.

A temperature increase represents a potential threat to aquatic communities, as it affects metabolism, feeding, spawning, egg incubation, growth, and migration of organisms.

The growth of fish may be stimulated by higher temperatures, but unless adequate oxygen and food are available no net productivity gain may be realized at this or other trophic levels. Crowding of organisms into attractive warm waters, lack of seasonal fluctuations in water temperature, and increases in metabolic rates may all interfere with the reproduction and decrease the vigor of organisms. Sublethal thermal effects include impairment of feeding ability, increased vulnerability to predators and diseases, and enhanced toxicity of poisons (National Research Council 1980). Subtle physiological and behavioral functions may change. Impacts differ by species and may result in shifts in aquatic communities due to changing abilities to compete and avoid predation.

Temperature increases may result in increased productivity or shifts in species composition, and may facilitate the growth of nuisance organisms, which in turn may decrease the oxygen available for other species. Thermal inputs will tend to cause a replacement of diatoms (which prefer 15° to 25° water) by green algae (25° to 35°C) or blue algae (30° to 40°C) (National Research Council 1980). Dissolved oxygen is reduced by increased temperature, and the rates of biological processes are increased, increasing the biological oxygen demand (BOD). If high organic loads or excess nutrients are present, oxygen depletion and eutrophication may result (National Research Council 1980).

Some species redistribute themselves along thermal gradients. Some invertebrate and fish species are attracted to the heated waters and feed on the algae and vegetation there.

Temperature impacts will depend on the depth at which heated effluent is discharged, the river volume, and the velocity, which together determine the dilution characteristics. Turbulent mixing, temperature stratification, and reverse tidal flow (in the Columbia) are all site-specific parameters which will determine the significance of thermal effects. Other energy developments (e.g., dams) also increase the river temperature. Individually, their temperature impacts may be insignificant, but cumulatively they can be great.

The intake of river water into the circulating water system will result in the destruction of entrained plankton, larvae, invertebrates, and some fish eggs. Under some conditions, entrainment and impingment mortalities can be significant (Jensen 1978). Current studies at Trojan and Hanford indicate insignificant impacts (Page et al. 1978, PG&E 1981).

The release of large quantities of heat and water vapor to the atmosphere by cooling towers may have significant effects on local climate, including increased incidence of ground level fogs, higher relative humidity, increased precipitation from drift, increased cloud formation, plume persistence, and even snowfall (National Research Council 1980). Indirect impacts may occur resulting in a change in food types and availability. Subtle vegetation changes might occur, and invertebrates such as insects may alter timing of oviposition, emergence, and other behavioral patterns in response to meteorological changes. The ecological impacts of these climatic and meteorological changes has not yet been demonstrated, but may be minimal, as their magnitude is well within normal weather fluctuations (National Research Council 1980).

Noise from circulating and falling water in a 500-foot hyperbolic cooling tower registers approximately 50 dBA at 2,000 to 2,500 feet and increases to 53 dBA with the addition of a second tower (Dinger 1976). Considering that animals generally habituate to routine sound levels up to 70 to 90 dBA, noise produced by cooling towers would not be expected to affect local wildlife populations.

Collision of birds with tall structures such as natural draft cooling towers has the potential to increase mortality, especially if constructed in well defined pathways. At the Trojan site, dead birds were not found near the cooling tower (Beak Consultants 1978) during repeated surveys in 1977.

3.3.3.1.2 Blowdown and wastewater. In addition to carrying waste heat, cooling waters contain residues of the chemicals used to control biological fouling, corrosion, or scale formation within cooling loops and distribution pipes. Historically, components containing chromates have been used, although nonchromate inhibitors containing zinc and phosphates are also used. The latter are more expensive and have not yet received wide acceptance.

Chromates in effluents are soluble salts capable of entering food chains through normal biological processes and concentrating in many organisms. Aquatic algae have been shown to concentrate 4,000 times above the levels in the immediate environment (Duffus 1980). As with other true elements, many factors affect plant and animal uptake, particularly the tolerance ability of the species.

A refinery may require four separate additional waste systems, each using a unique treatment. These systems include: 1) sour water system for ammonia and hydrogen sulfide bearing waters, 2) process sewer water system for hydrocarbon containing water, 3) storm sewer water system for rainwater runoff and nonprocess waters, and 4) sanitary water system to handle activated sludge and chlorinated effluent. The latter two are characteristic of all facilities. Discharging improperly treated wastes during the operation of any of these systems may lead to water pollution and a concomitant adverse impact to aquatic life.

The discharge water is mixed with river water, and the resultant concentrations are subject to conditions of an NPDES permit administered by the states. New facilities would be subject to similar requirements. Considerable monitoring of the water characteristics in the vicinity of the Trojan Plant is conducted. Details of the existing monitoring program and results obtained are available from Portland General Electric (Beak Consultants, Inc. 1978). Cooling water blowdown characteristics from a closed-cycle system, such as at Trojan, are shown in Table 3-21.

Chemical discharge to rivers as a result of plant operation are probably insignificant under normal operation; however, the effects of

Table 3-21. Typical amounts (lb/yr) of waste chemicals discharged in closed-cycle blowdown from a 1000 MW reactor.

Discharge	Amount (lb/yr)
Sulfuric acid	1×10^6
Chlorine	2×10^5
Copper (corrosion)	$0 - 2 \times 10^4$
Nickel (corrosion)	$0 - 2 \times 10^3$
Phosphate (anticorrosive)	3×10^4
Dispersing agent	1×10^4
TDS (concentration cycle)	$4 \times 10^6 - 4 \times 10^8$

Source: Zittel (1976).

chronic, low-level effluents have been poorly studied. The discharged chemicals include sulfates, phosphates, borates, zinc, copper, sodium, and lithium salts. Copper concentrations of 0.02 ppm are known to increase mortality and inhibit growth of Chinook fry; acute toxicity of zinc for cutthroat occurs at concentrations of 0.09 ppm (Battelle 1971; Becker and Thatcher 1973). Zinc and copper are also known to exhibit synergistic effects (lethal or interfering with migration) at concentrations below 15 percent. Levels of 0.02 ppm equal concentrations of zinc and copper constitute the avoidance threshold of Atlantic salmon (Battelle 1971). Similar data are not available for the Columbia River salmonids.

Chemicals released into the river in the cooling water discharge may ultimately enter the sediments in the river, the estuary, and the ocean. Due to the tremendous dilution available, the impact to the sediments may be negligible; however, long-term studies of chronic effects in complex environmental systems are lacking.

Chlorine, used as a biocide for condensers, sanitary waste systems, and makeup lines, may also be potentially harmful to aquatic organisms. Table 3-22 presents dose-response data for selected organisms. Combinations of chlorine and ammonia are especially toxic.

3.3.3.2.3 Salt drift. Chemicals added to the cooling water to prevent corrosion or scaling in the piping are also released with the drift drops from the cooling tower (water) and may be deposited on the adjacent terrestrial or aquatic systems. The deposition of chemicals from cooling tower operations is called salt drift. While the chemicals are transported through the air, their impacts are measured and evaluated in terms of the effect on the ground, water, and vegetation in the area. Air quality is not significantly deteriorated by these chemicals. In addition to salts,

Table 3-22. Response of several aquatic organisms to different concentrations (ppm) of chlorine in water.

Species	Concentration	Response
Coho salmon	0.05	Nonlethal
Pink salmon	0.05	Nonlethal
Brook trout	0.005	Depressed activity
Rainbow trout	0.001	Avoidance
Dungeness crab	trace	Highly sensitive

Sources: Battelle (1971), Becker and Thatcher (1973).

trace amounts of heavy metals, including arsenic, cadmium, lead, chromium, and mercury, have also been found in tower drift. The salt drift from the cooling towers has a negligible impact on the river and estuary, largely due to the tremendous dilution available. Additional information on the effect of saltdrifts may be found in BSAI (1982).

3.3.3.2 Ecosystem perspective. Thermal effluents are of serious concern, primarily in their potential effect on aquatic systems. The key factor for monitoring is not the possibly insignificant contribution of a single facility, but the cumulative thermal effect of all effluent sources on the aquatic system. Thermal changes in aquatic environments may affect water quality (concentration of dissolved gases and solids) and may shift species composition at all trophic levels of aquatic communities, thus affecting food chain structure. Shifts in plankton populations described above may affect higher trophic levels, as these primary producers play a key role in ecosystem dynamics. Warm water blue algae, which do not seem to be eaten as much as the green algae, are toxic to many forms of aquatic life (National Research Council 1980).

Chemicals present in circulating cooling water may enter the ecosystem as atmospheric drift from the cooling tower or as blowdown discharged to the river. Trace elements may be harmful and can be concentrated in food chains, but state-of-the-art control technology is probably adequate to render these potential impacts insiginificant. Chronic, long-term, low-level thermal or waste effluents may have significant, subtle effects in complex systems, but have not been sufficiently studied to allow judgement.

3.3.4 Fuel Delivery and Other Energy Related Transportation Facilities

3.3.4.1 Marine vessels. Vessels associated with energy developments in the Columbia River and Estuary are those carrying oil, LNG, LPG, fuel, coal, and OCS support equipment and personnel. The probability of significant increases in marine vessel traffic in the next 25 years is generally low to medium. At least one marine terminal is projected for the Columbia River Estuary within the next five years.

3.3.4.1.1 Significant estuarine impacts. Marine vessel impacts include those related to dredging, dredge disposal, and oil spills. These and the specific water parameters that may be affected are discussed below.

Dredging. The operation of marine vessels requires dredging and maintenance of channels. Maintenance dredging results in short-term impacts from excavation, and long-term impacts from changes in water characteristics. Ongoing dredging is required in support of existing shipping, and impacts should not be fully ascribed to the additional shipping associated with new energy developments. Increased shipping, however, may require increasing the depth of the dredged channel and entrance bar to admit deeper draft vessels.

In evaluating the impacts of dredging it must be noted that the river carries a large natural load of suspended sediments and that massive amounts of ash, mud, and other debris were deposited in the Columbia River by the eruptions of Mt. St. Helens. Future inputs from volcanic eruptions may continue to contribute to the maintenance dredging requirements of the Columbia River.

Oregon State University (1977) and Allen and Hardy (1980) provide detailed discussions of dredging impacts. Dredging of shipping channels and turning basins may alter existing circulation patterns and result in changes to the local water characteristics. Specifically, dredging changes the area and volume of water in channels thus changing residence times, mixing characteristics, density stratification, and temperature and salinity distribution. All of these parameters are inherently highly variable in the Columbia River and Estuary, thus making impact assessment difficult.

Specific water parameters of concern and how they may be affected by dredging are discussed below.

Salinity. Dredging affects salinity through alteration of estuarine circulation.

Temperature. Dredging may either raise or lower water temperatures by changing water depth and circulation patterns. Generally, the impacts due to altered temperatures caused by dredging in estuaries are very small.

Turbidity and suspended solids. Increases in turbidity and suspended solids from dredge removal and aquatic disposal are unavoidable. Turbidity must be monitored, and operations suspended when acceptable levels are exceeded. During biologically sensitive times, reduction, or even prohibition, of dredging may be necessary.

Nutrients. Nutrients released from sediments by dredging may stimulate phytoplankton and algae growth. Within estuaries, ammoniated nitrogen produced by bacterial metabolism of organic matter in the water column and sediments is the primary nutrient released by dredging (OSU 1977). In nutrient-deficient waters, the addition of ammonia and other nutrients could be beneficial (Allen and Hardy 1980).

Dissolved oxygen. Bacterial oxidation of soluble organics and the chemical oxidation of reduced inorganic compounds, which are released to the overlying aerobic waters during dredging, can reduce the dissolved oxygen content. In estimating dissolved oxygen depletion from dredging operations, there are numerous factors to consider, including dispersion, sedimentation, reaeration, and residence time of the affected water within the estuary.

Heavy metals. If heavy metals sources to the estuary or river can be identified, tests of the sediments should be conducted to determine concentrations (OSU 1977). The data should be input to a dispersion model for comparison to water quality criteria.

The toxicity of heavy metals in the water column is highly dependent upon both the physical and chemical behavior of the metals and the biological response of the organisms exposed. Heavy metals toxicity may also be compounded by synergistic effects (Olsson et al. 1979) which may amplify or moderate a toxic response. For biochemical interactions to occur, the metal must be in soluble form; however, not all soluble forms of a metal may be taken up by the organism or are reactive (Chapman 1978).

Toxic organics. Toxic organic compounds such as DDT and PCB's have a tendency to become associated with particulate matter and are not resolubilized. Buildup of these compounds within the sediment poses a problem to benthic organisms; however, dredging activities probably do not release sufficient quantities of these compounds to result in acute toxicity to organisms within the water (OSU 1977; Allen and Hardy 1980).

Dredging of new channels will change existing circulation and sedimentation patterns, greatly modifying aquatic ecosystems. Creager et al. (1980) noted that sediment size in the channels in the Columbia River Estuary was related to whether a channel was open to the main flow or blocked. Channel sediments are finer than those on the banks when channels are blocked, and coarser when open.

Sedimentation within estuaries effectively traps and removes from aquatic systems heavy metals, pesticides, such as PCB's, and many materials which, in excess, may be harmful to fish and wildlife. As long as the estuary remains a depositional environment, sediments may function as a sink for these materials. Dredging, however, removes sediments. In the process, buried materials, both natural and man-made, are resuspended into the water column and made available to aquatic organisms. Consequently, the composition of sediments in sites to be dredged must be evaluated to determine suitable disposal methods. Because the identification of materials which may be reintroduced into the water column is of great concern, tests should be run on the sediment samples.

The impact of navigational dredging on fauna may be significant depending on the type, size, and time of operation. Water quality parameters, especially turbidity and dissolved oxygen, alter the distribution and abundance of benthic organisms in the intertidal and subtidal zones. Bottom-dwelling marine organisms, principally benthic invertebrates, are not mobile enough to evacuate the dredging site. These organisms will be excavated with the dredged material.

Changing water quality may subtly influence plant productivity and species composition of benthic plants. Of particular significance are elevated levels of suspended sediments, redistribution of nutrients, decreases in dissolved oxygen, changes in temperature, possible resurfacing of heavy metals, and changes in underwater light intensities.

The response of benthic flora, floating vegetation, and other aquatic plants to increases or decreases in water quality parameters from dredging are difficult to distinguish, given the tremendous natural variability found in the estuary. Dispersed sediments can settle on rooted benthic vegetation and suffocate plants. Higher turbidity increases solar reflectance in the water column, reducing available light for photosynthesis. Additionally, reduction in dissolved oxygen or changes in salinity or nutrient concentrations can all influence photosynthesis and plant metabolism.

Dredging will remove organic material and expose underlying sand, silt, or mud, influencing the ability of plants to reestablish. Although recolonization of new channels can be either rapid or slow, depending on underlying substrate and the reproductive capability of remaining plants, continued disturbance will probably preclude successful revegetation.

The entire bottom community within the dredged area will be withdrawn with the dredged material and most likely not return to predredging composition or abundance, especially if maintenance dredging occurs frequently. Some populations will not achieve preoperational levels. Several species of clams, shore crabs, polychaetes, amphipods, and some less common invertebrates will be reduced by navigational dredging. However, high reproductive rates and short life cycles of smaller invertebrates (e.g., some polychaetes, amphipods, and clams) may enable these species to recolonize, reach maturity, and reproduce between maintenance operations. Long-lived species, including the larger clam and crabs, may not reach sexual maturity nor develop to the age of maximum reproduction between maintenance operation; these species will be represented only in juvenile stages and will be present in reduced numbers. The continued loss of detritivores and their functions will reduce the algae, zooplankton, aquatic invertebrates, and fish of higher trophic levels.

Suspended solids will also influence free floating filter feeders. Environmental effects of dredging on fisheries resource are directly linked to water quality. Increased turbity inhibits food takeup and can cause disorientation, while reduced dissolved oxygen may further exacerbate migration stress. Other sublethal effects include hematological compensation for reduced gas exchange across gill lamella, abrasion of sensitive epithelial tissues, and ingestion of solids, all of which reduce successful feeding and defense. Sometimes migration is delayed until the water clears.

The severity of these effects depends on fish age and species. Juveniles that are ocean bound, adults returning to spawn, and different species (flounder, salmon, or winter-run steelhead) may exhibit different tolerance to changing water quality. Species that exhibit year-round juvenile rearing may be severely affected, as well as bottomfish, such as flounder and cod, which are closely tied to the benthic food web. Although bottom fish are physiologically more tolerant of suspended solids than other species, loss of food may become a limiting factor.

Nursery areas for marine or upriver resident fish may also be reduced, depending on dredge location. Reduction of intertidal shallow water areas, where dredged material is often deposited, forces juvenile fish into deeper water, where they are subject to more intense predation. Many of these effects are subtle and are manifested gradually over many years; hence, they are not easily quantified.

Dredge disposal. The disposal of the sediment from existing maintenance dredging and of the debris from the Mt. St. Helens eruption is already a growing problem, as filling consumes existing wetlands and alters existing riparian habitat. The alternative of transporting dredged material beyond the estuary for disposal on the continental shelf is costly, but is already practiced to some extent. The timing of dredging may affect important biological functions, so dredging activities are generally planned to avoid critical times whenever possible.

Dredged material may be disposed in the open ocean, on the side of the channel, or on land. Dredged material can be used to create artificial habitats (islands or beaches). If disposal is made in the estuary, the characteristics of the dredged material will affect the sediments or soils at the disposal site. If dredge materials are placed in a higher energy environment than their original site, the action of waves and currents may carry them away (which may be a desired objective). The chemical characteristics of the sediment must be evaluated, as some materials which may be released to the water column may have unacceptable impacts.

Allen and Hardy (1980) describe the impacts of dredged material disposal in the estuarine environment in their comprehensive literature review, which included articles published by the U.S. Army Corps of Engineers Waterways Experiment Station concerning the study area.

Disposal of dredged material may pose significant impacts to plant and animal communities. Dredged materials may be deposited over intertidal habitats, or beaches, or near shore locations in the Columbia River Estuary and in riparian habitats upriver. This activity profoundly affects the entire community, as it completely eliminates existing vegetation and generally precludes reestablishment for many years, depending on the frequency of operation and dredge material characteristics. Sterile salty soils are especially toxic to some terrestrial vegetation, which have difficulty becoming established. Vegetation tolerant of such conditions differs significantly from the native vegetation it replaces and represents mainly naturalized weedy species of grasses, herbs, and shrubs.

The final elevation of dredged material is generally much higher than that of the receiving area. Additionally, the material may vary in composition and texture. Both factors determine the drainage characteristics and, for many diked spoils, produce a seasonally-flooded, fine-silted dredge deposit area surrounded by a coarse-grained, better drained containment dike.

Dredged material is frequently placed in intertidal locations where certain wildlife species may be specifically affected. Shore birds and wading birds that find abundant amphipods and polychaetes in the finer sediments of mud flats and beaches will be displaced from foraging habitat. Grazing ducks (e.g., widgeons, mallards, etc.) and Canada geese will likewise be displaced if marsh habitats are filled. For example, in Gray's harbor eleven times more waterfowl use has been recorded in the undredged South Channel than in the dredged North Channel (Smith and Mudd 1976), and gull and tern use was three times higher. Fish eating waterbirds, however, used the North Channel 1.5 times more frequently than the South Channel (Smith and Mudd 1976). These differences were related to the shallow water and tide flat habitat available in the undredged channel, as opposed to deeper water, steeper sides, and less exposed substrate in the dredged channel. The unconfined disposal of dredged material further eliminates high quality waterbird and shorebird feeding areas.

Direct mammalian impacts from vessel traffic and dredging activity are expected to occur. If dispersed on intertidal and upland locations, unconfined dredged material, such as that from pipeline operations, will kill small nonmobile mammals and smother the habitats of numerous larger mobile species. Voles, shrews, and jumping mice would most likely be locally extirpated, whereas medium sized furbearers, including nutria and muskrats, will lose feeding and nesting habitats. Locally, large marine (e.g., harbor seal, otter, raccoon) and terrestrial (e.g., deer and bear) mammals would be affected through changing densities of food availability and species density.

The importance of marsh plants to birds is well known. Waterfowl such as widgeon and mallards graze on salt marsh plants, and some shorebirds including sandpipers and dunlin selectively feed on their seeds. Nutria, muskrat, Townsend's vole, and other grazing mammals also heavily depend on wetland vegetation for food and shelter. Loss of wetlands through dredge deposits would directly reduce their numbers and simultaneously decrease the food base of their avian and mammalian predators.

As elevation is increased by filling and vegetation is reestablished, dredge disposal sites may provide feeding and nesting habitats for upland birds and mammals, rather than for the traditional water dependent species. Passerines, especially migrants, and game birds may become more abundant, as will small mammals such as field mice and gophers.

Oil spills. The operation of marine vessels in the estuary presents the risk of spilling oil or other fossil-fuels. Although the risk is low, the consequences of a major accident may be catastrophic. The effects of oil spills are treated generically in Section 3.3.2.1.

3.3.4.1.3 Ecosystem Perspective. Vessel traffic itself will have minimal direct effect on ecosystems within the Columbia River Estuary.

Support activities, primarily dredging and disposal, exhibit a much greater ability to alter trophic structure. Any major losses of phytoplankton in the aquatic community or wetland vegetation in the intertidal and riparian communities will reduce the availability of nutrients in both the form of decomposed matter and as primary production (e.g., in the form of growing plants). Such a loss will directly influence the populations and species of detritus feeders and aquatic and terrestrial herbivores.

Detritus feeders and the food web based upon them will be uprooted and severely affected by dredging and resultant water quality changes. The grazer based food web will also be affected by both dredging and disposal activities. Oil spills may contaminate wetland and aquatic communities and become incorporated in bottom sediments, where effects may persist for a long period.

3.3.4.2 Marine terminals and fuel storage. Marine terminals are required for the transshipment and redistribution of imported raw product and the export of finished product. Types of transshipment are primarily oil from tanker to pipeline, and coal from train or slurry pipeline to barge or ship. Terminals integrate water, rail, pipeline facilities, and fuel storage at a suitable location where all modes of transshipment can be accommodated. Preferred locations are those areas where berthing facilities exist or may be readily built, and where access to existing rail lines is available.

Large amounts of waterborne raw materials and/or finished products are certain to be transported via the Columbia River Estuary by water, and rail and pipeline services at marine terminals will undoubtedly be an integral part of this material movement in support of most types of energy development.

Development activities associated with terminals include the construction of berthing facilities (requiring dredging) and of new or upgraded rail services, especially large capacity lines. Additionally, large tracts of land for product storage and handling will be required.

3.3.4.2.1 Significant estuarine impacts. Impacts associated with marine terminals include those related to landfill and land use, maintenance dredging, and fuel transshipment, storage, and handling are discussed below.

Landfill and land use. A primary impact associated with terminal development is the filling and building on wetlands and estuarine environments. Effects of fill from dredge disposal are relevant and are discussed in Section 3.3.5.1 above. The impacts associated with construction are discussed in Sections 3.2.1 and 3.2.2.

Rail facilities, especially those required for loading, unloading, and stockpiling coal, require large lowland areas, which along the Columbia River would very likely be on wetland or riparian habitats. Fill from adjacent uplands would be required to provide a solid substrate for switching yards and transfer machinery.

Maintenance dredging. Maintenance dredging of the harbor and the disposal of dredged material associated with terminal facilities present ongoing impacts to both water quality and to fish and wildlife. The impacts of dredging on fish and wildlife are described in Section 3.3.5.1.

Fuel transshipment. The transshipment of liquid fuels, although primarily impacting air quality, constitutes a threat from spillage and chronic low-level leakage during transfer operations. Minor spills do occur and are normally contained by devices such as booms, dikes, drip pans, etc. These spills may have acute and cumulative impacts; this hazard of marine terminals is discussed in Section 3.3.2.1.

Combustion products are released from the operation of machinery at the terminal and from the engines of marine vessels. During transfer operations, air quality is also impacted by hydrocarbon emissions from tankers, barges, and upland storage tanks. Turbidity will be increased by the propwash of the marine vessels and tugboats during docking.

Fuel storage and handling. Air quality may be polluted where coal is shipped and stored. Fugitive dust emissions (coal particles that escape to the air during loading, transmittal, and storage) are a potential problem. The draft EIS, (U.S. Army Corps of Engineers 1981) for a coal terminal at Kalama (river mile 71) estimated coal dust emissions of 150 tons per year with the best available technology. The control of coal dust is discussed in Section 7.4.6.1.

Water quality at the site may be endangered by runoff from coal stockpiles or leaching of oil. At and near the storage and transfer sites, the chemical composition of soils may be altered by coal dust, spilled oils, leachates, or stockpiled coal.

Terminals are generally characterized by cleared land, since vegetation encumbers the handling of materials and reduces storage capabilities. Vegetation remaining at the site is expected to be adversely affected by operation activities, particularly ground disturbance and soil compaction from machinery. Fugitive dust from operation and storage activities over extended periods may reduce the vitality of any vegetation near the site. Chronic runoff containing leachate from coal piles, spilled fuels, and miscellaneous toxins will further affect plant communities.

Residues and leachate from stored material may harm fish and wildlife. If not collected and treated at onsite facilities, coal pile runoff may carry toxic substances into adjacent habitats. Additionally, fugitive dust settling in rain and surface runoff may increase turbidity and sedimentation in nearby waters.

Onshore storage facilities for OCS support differ according to the amount of storage required. This is a function of the method of transshipment selected (marine vessel or pipeline) and the rate of production of the field. Storage facilities consist of tank farms, pumping stations, containment devices, and pipelines to and from the development. Onshore storage consumes large areas of land, but is not water dependent, so it may be located inland from the estuary.

For natural gas brought ashore by pipeline, treatment and pumping facilities would be required. Since gas production would likely be of a significant scale to justify construction of an offshore pipeline, these facilities could occupy 50 to 75 acres and require 200,000 gallons of water per day (OSU Sea Grant 1978). There is also a greater possibility that liquified storage would be considered in such a situation, particularly if the coastal site offered opportunities for combined development of an LNG receiving terminal.

3.3.4.2.2 Ecosystem perspective. Ecosystem effects are primarily related to routine operation and maintenance activies, such as dredging, handling of fuels in transshipment, and storage of fuels. Fugitive emissions and uncontained runoff or leachate entering water, soil, and air are the primary pathway taken by hazardous materials. A breakdown in control technology or a serious accident provides another means of serious impact. If toxic materials are released in large quantities, entire ecosystems may be profoundly affected. Dredging impacts are discussed in Section 3.3.4.1.2.

3.3.4.3 Railroad and truck transportation. Rail and truck operations will be required to deliver raw materials or distribute finished products to most energy related facilities built in the Columbia River Estuary. Support activity will be most significant during construction, when barging and berthing facilities are not yet built, and the only method of access and delivery to the site is via land. Truck and rail are necessary to deliver heavy construction equipment, plant machinery, and building materials. Although a major siting criteria for facilities is the proximity to existing truck and rail lines (trucks currently run on one or both sides of the river from Astoria to Portland), new access lines to the site and modernization of existing older highways and rail lines are expected.

3.3.4.3.1 Significant estuarine impacts. Rail and truck traffic and the maintenance of rail lines and highways are expected to have minimum impacts under normal operating conditions. Emission and noise from rail and truck are regulatd by the USEPA. Nevertheless, in certain locations such as steep highway grades, both emission and noise standards may be temporarily exceeded.

Although rail and highway maintenance operations are distributed over the entire corridor, frequent delivery of construction materials or fuel (e.g., coal by unit train) at a site may present serious chronic noise hazard or fugitive dust problems. A unit train carrying a typical load (e.g., 10,000 tons) may emit 5 to 100 tons of airborne dust over a 300 mile route (USEPA 1978).

Storm water runoff from the surface of highways and smaller roads, if not adequately drained or channeled, may result in erosion and damage to adjacent land. Runoff would be proportional to the area of impervious surface and is influenced by topography, placement of culverts, drainage ditches, and the infiltration capacity of roadside soils. Existing streams may prove inadequate to handle elevated runoff from impervious surface areas. Railroad beds pose similar problems since they also inhibit the natural flow of surface water and may require construction of bridge crossings and channelization of rivers and streams.

Once rail and truck roadbeds are built, additional impacts to soils and sediments attributable to operation are minor. Maintenance activities such as resurfacing highways will disturb soil on a limited and localized basis. Transportation activities on gravel, dirt, and other tertiary roads will result in ongoing erosion with a possibility of concomitant sedimentation. Traffic on primary, well surfaced roads should have little additional impacts.

Maintenance will continue to influence nearby vegetation after completion of construction. Truck and rail traffic may emit noxious fumes and raise dirt and dust which may damage roadside vegetation. Heavy metals in emissions may be concentrated by some species. Runoff containing petroleum products such as oil and gas may damage corridor vegetation. Fugitive dust from coal unit trains may coat the leaves of nearby vegetation, reducing its photosynthetic capability, and may plug soil pores, prevent percolation, and have toxic effects on wildlife (USEPA 1978).

Vegetation maintenance in the corridor will shape community structure and composition to meet management goals. The improper application of herbicides can damage nontarget species and adversely impact aquatic organisms that receive runoff.

Railroad tracks are generally placed on elevated crushed rock or gravel beds, enabling rapid water drainage and providing a poor colonization substrate for vegetation. Additionally, the leaching of creosote from railroad ties prevents vegetation from becoming established nearby. Volatization of noxious hydrocarbons from treated railroad ties may also impair gaseous exchange capacities of vegetation. Dirt and gravel roads may require ongoing maintenance activity to reduce encroachment by plants.

Wildlife abundance will vary along railroads and highway roadsides depending on location, frequency of use, corridor vegetation, and season. Roadside edge frequently attracts small mammals, deer, and other grazing animals to feed on succulent forage not available in adjacent forests. Increased road-kills, however, may offset any benefit derived by this edge effect.

Surface runoff from highways and railways may contain a variety of pollutants and toxins derived from tire residues, oils, greases, and gasolines leaking from wheels, and derivatives of pavement binders and asphalt, which are directly harmful to wildlife. Runoff has been shown to contain such chemicals as chromium, phenols, puric acid, fuel oil, gasoline, and fertilizers in addition to organic wastes; and human and animal bacteria (Real Estate Corporation 1974). Contamination of streams, lakes, and other bodies of water from surface runoff with high concentrations of these substances is a possibility. These substances may also infiltrate to groundwater.

Roadways and railways may function as barriers to small mammal migration and may temporarily hinder dispersal of larger mammals. Vehicle traffic may simply scare species or channel their movements parallel to the roadway. Immature, dispersing animals unaccustomed to traffic may be most affected by roadways and most susceptible to accidents.

3.3.4.3.3 Ecosystem perspective. In general, road and railway construction, both past and future, should have only minor ecosystem effects. Rail and roadways may affect the distribution of plants and wildlife, increase access and hunting pressure to previously unaccessible populations, and lead to increased road-kills of wildlife. On the other hand, roadways add local diversity, in the form of corridor edge, to surrounding habitat.

ROW maintenance often requires the periodic application of toxic materials to control roadside vegetation. These materials may adversely affect adjacent vegetation and wildlife and are easily transferred to aquatic systems where they may concentrate within animals of higher trophic levels.

Spillage from derailment and highway accidents pose the greatest threat to natural systems. Burlington Northern runs parallel to the shore, and a substantial number of highways traverse the Columbia River. Bridges also cross the tributary streams in the study area. The proximity to streams suggests that accidents may have wide-range effects. LPG is transported by track or train; an accident resulting in a large spill could result in an explosion.

3.3.4.4 Electric transmission lines. No transmission line crossings occur, or are projected, within the estuary. A few river crossings are made between river miles 50 and 100. Transmission lines carry electricity in bulk, at high voltages. Such facilities may be required for new electric generating projects; however, if new thermal, central station generation is developed in the study area, it most probably will be associated with existing plant sites, at Trojan (nuclear) or Port Westward (fossil-fuel). In such cases, the existing transmission grid would be used, although certain lines may need reinforcement, and existing corridors may be expanded. New small hydro projects may require new, short transmission corridors. Probabilities associated with major new transmission projects in either the Washington or Oregon side of the estuary are generally low, although a medium probability is associated with the more densely populated Oregon side in the 25-year period.

3.3.4.4.1 Significant estuarine impacts. The impacts of electric transmission lines discussed in this section include those related to avian mortality, electric line effects, and maintenance of towers and ROW's.

Avian collisions (waterfowl and shorebirds). Transmission towers and conductors, when located on or near waterfowl concentration areas or when traversing major flight paths, will cause avian mortalities from collisions with structures and wires. The significance of transmission line induced mortality to waterfowl and shorebirds has been reported and discussed by Cornwell (1968), Banks (1975), Stout and Cornwell (1976), Willard et al.

(1977), Anderson (1978), Meyer (1978), Thompson (1978), and James and Haak (1979). The general consensus of this research is that, while incidents of substantial mortalities occur, population effects have not been significant.

Stout and Cornwell (1976) estimated that wire strikes are less than 0.1 percent of total nonhunting mortality for waterfowl. Presumably, kills due to strikes with major powerlines would be substantially less than the above cited figure. The exact magnitude of the problem is unknown (Lee 1977).

Mortality in specific cases and with certain species is reported to be significant. Anderson (1978), in a worst-case situation where twin 345-kV powerlines transected a concentration area of waterfowl, reported annual mortality rates at 0.2 to 0.4 percent. The birds' flight behavior was such that they avoided traversing the lines (only 4 percent of the observed flights traversed the lines). Flight avoidance is apparently typical and has been reported by others.

Swans, cranes, green-winged teal, red phalarope, and possibly the white pelican seem to strike powerlines more frequently than other species. For some of these, particularly swans and sandhill cranes, mortality due to powerline collisions can be excessive, with annual mortality rates of 30 percent or more being reported (Harrison 1963; Drewien 1973). Additional species-specific information for waterfowl and shorebirds is provided in Section 5.9.12.

Electric line effects. The biological effects of static and low frequency electromagnetic fields on plants and animals have only recently been examined. The effects of acute or chronic exposure are not fully known and are controversial. Some preliminary laboratory studies indicate no adverse impacts on small mammals (Phillips and Kaune 1977) or on the growth of certain crops (Hodges et al. 1974). In a recent review of the literature, IIT Research Institute (1979) concluded "...that it is highly improbable that electric fields from transmission lines have any significant biological effects on healthy individuals who encounter such fields in a normal way under ordinary conditions."

The potential impact of oxidants created in the corona (charged atmosphere around the transmission line), particularly ozone, has caused some concern. Laboratory and field studies, however, have confirmed that oxidant production associated with EHV transmission lines are low and not distinguishable from ambient levels at ground level (Frydman and Shih 1974; Sebo et al. 1976).

The issue of audible noise from the larger powerlines affecting wildlife behavior has been raised in numerous impact statements. Significant impacts due to noise by transmission lines are unlikely. Many species are known to habituate to constant noise without observable harmful effects, even when the noise source was designed to deter wildlife presence.

Electrocutions of raptors, particularly juvenile eagles, due to distribution lines have been documented (Hannum et al. 1974; Miller et al. 1975; Nelson 1976; Howard and Gore 1980). Ordinarily, high voltage transmission line conductors are sufficiently separated and do not pose a hazard to eagles or hawks (Hannum et al. 1974; Olendorff et al. 1981). The electrocution of raptors or other large birds occurs almost exclusively on single pole distribution lines (Baldridge 1977).

Hazards associated with transmission lines result from situations which could cause a live wire to drop to the land or water. This could result from heavy icing (as has occurred twice in Portland in the last five years), sabotage (as was threatened in the Portland area several years ago), forest fire, earthquake, or volcanic activity.

On land, downed lines pose a fire hazard, especially in the dry season. A shock hazard exists from fallen lines both on land and in water.

Maintenance of towers and ROW's. The effects of clearcutting and maintaining ROW's discussed in Sections 3.2.3 and 3.3.5.3 are applicable. Dirt roads are required paralleling transmission lines to provide maintenance access.

The use of herbicides for ROW management is now common in areas adjacent to the Columbia River Estuary. Table 3-23 documents herbicides likely to be used in the region. Some change in species mix due to repeated application of herbicides is anticipated, but this will depend on original community, seed source, and herbicides used, and whether selective or broadcast methods are used. A review of the effects of herbicide application has recently been completed by Galvin et al. (1979). The effects of specific herbicides on plant species is reported by Devaney (1968), Cody (1975), and Bovey (1977). The effects on riparian vegetation is thought to be particularly significant (Galvin et al. 1979). Newton and Norgren (1977) have reviewed in detail the potential impacts of silviculture chemicals, including herbicides, used in ROW maintenance and their impacts on water quality and aquatic biota.

Effects of herbicides on water quality are dependent on application rates, application methods, and herbicide selected. Water quality effects following standard applications are typically short-term and do not pose significant impacts (Newton and Norgren 1977). Direct application over water courses could cause deleterious effects. There exists an extensive literature on herbicides (Dailey 1978; Galvin and Cupit 1979), and although Mullison (1970), Newton and Norgren (1977), and others report no significiant water quality impacts, the topic is controversial (George 1962; Roan and Ware 1970) and of public concern. Of particular concern is the use of compounds (Dioxin) which in the past have been contaminated with 2, 4, 7, 8 Tetrachlorodibenzo-paradioxin, a teratogenic compound.

The operational effects of transmission line ROW's on wildlife have been reviewed by Galvin et al. (1979), Dailey (1978), Galvin and Cupit (1979), and IIT Research Institute (1979).

Table 3-23. Herbicides for controlling foilage and their biological significance.

Herbicide	Action[a]	Uses as a herbicide	Biological consequences
Ammonium sulfamate (Ammate)	HGR	Stem-foliar application; especially effective in control of poison ivy, poison oak, and poison sumac.	Safe for use around water and crops.
Trichlorobenzoic acid (TBA)	HGR	Often used to increase spectrum of kill as additive.	Spray drift may injure adjacent crops and natural vegetation.
Bromacil (Hyvar)	HGR	Basal treatment in a water solution. Leaves drop quickly after treatment, so brownout problems are eliminated.	May persist in soil.
Dicamba (Banvel)	HGR	Often used in combination with other herbicides; controls sprouting of stumps and stubble. Effective on hard-to-kill species of trees and shrubs.	Selectively kills some grasses.
Karbutilate	HGR	Basal treatment in a water solution; controls sprouting of stumps & stubble.	Persists in soil.
Picloram (Tordon)	HGR	Stem-foliar application; basal application; treating stumps. Used mainly in combination with other herbicides; effects are usually additive. Effective against many woody plants. Delayed killing action.	Persists in soil.
2,4-D	HGR	Stem-foliar application. Kills both woody & herbaceous vegetation.	Kills some species of grasses.
2,3,5-T	HGR	Stem-foliar application. More effective woody plant killer than 2,4-D.	Selectively kills some grasses.
2,4-DP	HGR	Stem-foliar application. Controls root-suckering plant species.	---
Silvex (2,4,5-TP)	HGR	Stem-foliar application. Controls some species, including maple & oak, that are resistant to 2,4-D & 2,4,5-T.	Persists in soil.
MCPA (2-methyl-4-chlorophenoxyacetic acid)	HGR	Stem-foliar application.	Safe around croplands. When added to other herbicides, gives wider spectrum control.
Dichlobenil	GI	Retards growth of young trees; prevents germination of seeds. Applied to the soil. Affects both monocots & dicots.	---
Naphthalene acetic acid (Tree-Hold)	GI	Prevents sprouting from stumps & trimmed branches.	---
Chlorflurenol	GI	Prevents sprouting from stumps & trimmed branches.	---
Fenuron	GI	Retards tree growth & germination of seeds. Applied to the soil.	Suitable as soil-sterilant in dry areas only.

Source: Summarized from Carvell 1973, Barnhart et al. 1976, and Bovey 1977.

[a] HGR -- hormone growth regulator. GI -- growth inhibitor.

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The effects of ROW operation on wildlife are varied, favoring some species under certain conditions of habitat manipulation and reducing populations of others. Early seral wildlife and edge species such as black-tailed deer, white footed mouse, and meadow voles would benefit from ROW's through forested areas of the Columbia River Estuary, whereas climax forest species such as flying squirrel and spotted owl would be deleteriously affected. Species requiring old-growth forests for survival are listed in the CPCR, Vol. 2 Section 3.2.4. Species dependent on early successional plant communities are given in Volume 3 (see Western Hemlock and Sitka Spruce Zones). Community and respective species shifts attributable to ROW's are documented for numerous areas outside the region (Dailey 1978; Galvin and Cupit 1979), but similar effects are expected along the Columbia River. In general, ROW's do not appear to inhibit wildlife movement (Goodwin 1975; Schreiber and Graves 1977).

Beneficial impacts may also occur. For example, towers may provide nesting and hunting perches for many raptors, although the significance of this in the Columbia River Estuary is uncertain. Lattice steel towers for these high voltage lines have been used as nesting sites by golden eagles, red-tailed hawks, Swainson's hawks, peregrine falcons, great horned owls, and other raptors (Baldridge 1977; Thelander, BSAI; pers. comm.). In some cases, cormorants use transmission towers for nesting and drying (Garcia, BSAI; pers. comm.).

Indirect but significant impacts on wildlife are caused by easy access of off-road vehicles (ORV) resulting in greater disturbance and hunting pressure along ROW's and access routes (Goodwin 1975).

Temperature increase due to removal of riparian vegetation in small streams has been well documented (Brown and Krygier 1970; Brown 1970, 1974). This impact has been related to ROW's by Heisler and Herrington (1973) and Galvin et al. (1979). A single ROW crossing of a stream likely would have only a minor effect, but large ROW's running along a stream drainage can be expected to have measurable and potentially deleterious effects on stream temperatures and dependent biota. Small streams with low summer flows are particularly susceptible (Brown 1969).

3.3.4.4.2 Ecosystem perspective. ROW's across forested areas that are already limited in size can further reduce carrying capacity by eliminating scarce cover and breeding sites. ROW's across wetlands, grasslands, and shrublands can be expected to have primarily short-term construction related habitat effects, while ROW's through forested communities can be expected to cause long-term community shifts. Riparian communities and associated small streams are particularly vulnerable to ROW management techniques, especially those which reduce shading thus affecting temperature and carrying capacity of the stream (Brown and Krygier 1970; Brown 1970; USEPA 1971; Douglass and Seehorn 1975; Webster and Wallace 1975; Burns 1972).

3.3.4.5 Pipelines. Pipelines for transportation of gas, oil, or slurry coal may be operated in conjunction with oil and gas extraction in the estuary or as OCS support; they may deliver coal slurry to a gasification unit at Port Westward, for conversion and combustion in the existing

Beaver plant or a new unit; they may deliver products to transshipment points or to ultimate consumers from refineries, LNG, or LPG processing centers, or terminals served by marine vessels in the estuary; or they may simply cross the study area en route from a wholesaler or distributor to consumers on the other side of the Columbia River.

The probability that these associated facilities will be located in the Columbia River study area ranges from low for LNG, by 2006, to high for a second unit at Beaver, from 1987 to 1996.

3.3.4.5.1 Significant estuarine impacts. The routine operation of pipelines in the Columbia River study area poses few additional impacts to those realized in the construction of them. Some noise would be associated with pumping or compressor stations. These stations typically have silencers and do not pose a significant impact. However, under emergency conditions, unmuffled compressor stations in a blowdown operation will generate an estimated audible noise of 120-140 dBA over a one and a half hour period at a distance of 100 feet (Alcan Pipeline Company 1976; Northwest Pipeline Corporation 1976).

The washing out of pipelines in stream beds and the erosional problems along banks have proven to be continuous operational problems at stream crossings and can subject aquatic communities to adverse impacts (Northwest Pipeline Corporation 1976).

After pipelines are constructed, they are tested hydrostatically. Improper discharge of the wash liquid can pose toxic hazards to aquatic communities (Northwest Pipeline Corporation 1980). The water used for the testing may be voluminous, and unrestricted discharges can cause erosion and sedimentation. Also, extraction of water for hydrostatic testing during low summer flows could pose a problem. The discharges of the testing water require water quality monitoring under Section 308 of the Clean Water Act as administered by the USEPA.

If coal is delivered to the site by coal slurry pipelines, the water must be separated from the slurry and treated before it can be dispersed or used, thus presenting a wastewater disposal problem. Contaminants include chromates, phosphates, and various organic compounds, added to the slurry to reduce corrosion, as well as dissolved minerals from the coal itself, including shales, kaolins, sulfides, carbonates, chlorides, and oxides (USEPA 1978). The exact occurrence and concentration depends on the coal itself.

Rupture of the pipeline poses the hazards associated with spills of petroleum products, natural gas, or coal slurry. Obviously gas, oil, and coal slurry pipelines pose differing adverse effects if ruptured. The impacts of an oil pipeline rupture on terrestrial communities are not well documented. A small leak of a buried oil or coal slurry pipeline would be difficult to detect and could seriously contaminate groundwater aquifers if undetected long enough. Generic effects of oil spills are discussed in Section 3.3.2.1.

Pipeline rupture could result from earthquakes, landslides, stream/river washout, or sabotage. Where pipelines cross the Columbia River, rupture could result from a vessel dragging anchor, although prohibitions of vessels anchoring near pipeline crossing and the presence of a Columbia River pilot on board all marine vessels should prevent this from occurring.

3.3.4.5.2 Ecosystem perspective. Routine operation of pipelines presents little threat to ecosystem processes. The primary ecosystem path of entry for transported toxic materials is through leak or rupture of the containment vessel. Depending on the location of such a leak, fossil-fuels could enter soil or aquatic cycles, where they may be taken up by surrounding organisms, enter the food chain, and contribute to the mortality of fish and wildlife.

3.3.5 Fossil-Fuel Extraction Facilities

3.3.5.1 Oil and gas wells. A few gas wells are now in commercial operation, and exploration rights have been sold along the Columbia River in the vicinity of the Clatsop-Columbia county line, near Cathlamet and Puget Island in Wahkiakum County, and at several other locations. Wells may produce both oil and gas simultanously, but oil appears to be less likely than gas in the study area. The exploration and resource development phase includes activities prior to commercial production and differs from operation (i.e., recovery) in that it is generally a less intense effort spread over many sites covering large areas. Included are exploration, site preparation, drilling, mud circulation, and well completion stages. The operational stage primarily concerns recovery and maintenance activities, frequently including the piping of oil or gas.

At the well-head, the construction of semi-permanent facilities to protect equipment and to temporarily house personnel, gathering lines, pipelines, and pumping stations is required.

3.3.5.1.1 Significant estuarine impacts. The impacts of exploration and development are combined with recovery for discussion. Environmental effects depend predominantly upon local site characteristics and the specific drilling method employed.

Exhaust fumes from construction and drilling equipment and fugitive gases escaping from borings are the two major sources of air pollution associated with oil and gas exploration.

Evaporative loss of hydrocarbons occur from the numerous pipelines, valves, seals, and tanks located at platforms, pump stations, and transfer terminals. In remote locations, leaks may not be immediately located and may become a significant environmental problem.

Hydrogen sulfide, hydrocarbons, oxides of nitrogen and sulfer, and other fugitive gases are associated with drilling or venting, or may escape from the well-head. Small quantities generally escape into the atmosphere; however, larger volumes are vented or flared off at a safe distance from the drilling operations.

Acoustic techniques used in exploration produce significant, discontinuous noise levels. Chronic noise is produced by gas turbines and diesel motors at the pumping sites, compressor stations, and transfer facilities.

The effects of gas and oil exploration on water are varied and could be significant. One important consideration is the potential draining of aquifers to supply the solvent for drilling muds and to use for injection water. Local geology and size of operations will determine the number of injection wells and the volumes required to stabilize ground formations.

A related concern is the contamination of aquifer zones by drilling fluids, brines, or hydrocarbons in secondary recovery and drilling operations. The deposit of large quantities of brines is another serious problem (Reid and Streebin 1972; Reid et al. 1974). Drill muds may escape into porous formations and reach freshwater aquifers during drilling operations (Wilkins 1977). Modern operations using casings and other methods to protect aquifers greatly reduce the risk of such contamination. Spills at the well-head and along pumping routes are anticipated to be confined or low in volume and will not seriously contaminate runoff, surface streams, or rivers.

Exploratory drilling will produce cuttings and generate surplus mud which has to be disposed. Drilling muds include additives such as clay and bentonite in water and other chemicals such as lignosulfonates, calcium, and chromium. Together with cuttings, these are stored in waste pits, taking up space and contaminating soils. Minimum circulating and fill mud requirements include one cubic yard for approximately every 9 to 14 meters of drilling and 20 to 40 (and possibly 900) kilograms of chemical additives per day (Wilkins 1977).

Treating underground formations with acid to maintain their production results in the discharge of salt-enriched acid solutions which present a disposal problem because of their low pH and high solids content (Wilkins 1977). The acid may also corrode pipes, leading to failure and soil contamination.

As part of the exploration phase, core samples are gathered for hydrocarbon analysis at different intervals throughout the study area. Additionally, electric discharges, encapsulated explosives, gas gurs, and electromechanical and mechanical transducers are set at or near the ground surface for shock wave reflection analysis (Wilkins 1977). Sometimes a technique known as thumping, dropping a 2,700 kg steel slab from three meters, is used for shock wave analysis. The impacts from all these methods depends on local soil characteristics and surface geology.

The decrease in fluid pressure in oil and gas zones, due to the removal of fuel and water, may cause land subsidence. At sea level the submergence of land surfaces has lead to flooding of drains and sewers and overflowing of canals and channels. Upland subsidence is harder to detect, because of repeated leveling (Poland and Davis 1971). Subsidence, if it occurs, may alter soil characteristics and the water table, thereby indirectly influencing plant growth.

Water injections are currently used to control subsidence and to increase oil recovery. Injection water is obtained by tapping shallow aquifers. Groundwater withdrawal, however, may also lead to subsidence although there are marked differences in character and dimension between oil or gas and water reservoirs.

Accidental fuel spillage from either construction or drilling or from the well-head itself, will cause death and injury to exposed vegetation. Toxic spills of drilling mud additives will lead to reduced plant cover. Slant, or directional drilling from resilient, less fragile communities may protect more sensitive vegetation above potential oil or gas deposits.

Oil and gas exploration and recovery pose several hazards to fish and wildlife and their habitat. Underground and underwater explosions may result in harmful vibrations. The effects of such explosions on aquatic biota are discussed in Section 3.2.2.2. Uncontrolled subsidence may lead to structural failure of buildings, pipelines, and other engineering structures, possibly resulting in accidental fuel spillage. Subsidence at other locations may affect water depth and quality and affect fish, or may alter soil moisture holding capacity or depth to groundwater, influencing plant productivity and species composition.

More direct influences result from uncontrolled spillage at the wellhead, especially during exploration. Oil effects on both terrestrial and aquatic plants and animals are discussed in Section 3.3.2.1. Gases and oil under pressure may cover considerable distances, with oil sometimes being spread into the air and saturating plants 200 km away. Drilling and extraction within, or immediately adjacent to, the estuary poses an additional problem of spillage which may flow through sloughs and along shorelines, impacting wetlands and contaminating beaches and mudflats. In the estuary, tide and currents may redistribute spills to distant locations.

3.3.5.1.2 Ecosystem perspective. Oil and gas wells may profoundly affect geophysical parameters of ecosystems, through draining or contaminating aquifers, land subsidence, or accidental release of extracted fossil-fuels. Escape of drilling fluids, brines, or muds into the soils or waters where recovery occurs may seriously affect salinity, pH, and other conditions important to life. Effects of oil products in ecosystems are discussed in Section 3.3.2. Oil residues may enter sediments and prolong the effects of an accidental release.

3.3.5.2 OCS development. The potential for oil and gas off the coast of Washington and Oregon is probably minimal, however, surveying continues. If significant exploration and development occurs, Grays Harbor and the Columbia River Estuary may become major OCS support bases. Kaiser Steel has applied for a permit and filed a Final Environmental Impact Statement to fill a wetland site in Grays Harbor, Washington, to develop a facility for manufacture and assembly of offshore drilling platforms (U.S. Army Corps of Engineers 1976). Since the application, no progress has been made on this development. As mentioned in Section 2.5, a fabrication yard for platforms to be used in Alaskan OCS development was proposed for a site on the east bank of the Skipanon River mouth, although these plans have since been abandoned. If interest in the Washington and Oregon OCS resources is revived, then these and other plans may be realized. A recent study by the OIW (1979) concluded that the offshore wave environment at the mouth of the Columbia is too severe to favor OCS development.

Facilities associated with OCS support include: platform fabrication yards; pipelines coating yards; initial, temporary staging areas for movement of equipment, supplies, and personnel to offshore rigs; permanent production services bases; and extraction product storage facilities, which may include tank farms, pumping stations, containment facilities, liquified storage, and pipelines. Marine terminals, including pilings and piers would be required. Onshore pipelines would probably not enter the estuary.

3.3.5.2.2 Significant estuarine impacts. OCS support facilities are the primary source of OCS development related impact to the estuary. These impacts begin prior to the operation of OCS fields themselves. Some OCS support facilities will be operational, while others will still be under construction. A fabrication yard operation essentially continues construction phase activities, with impacts such as noise and machinery emissions as discussed in Section 3.2.1. Water usage by a fabrication yard varies, depending on whether or not steel is rolled onsite, and may be as high as 1,000,000 gallons per day (OSU Sea Grant 1978).

Considerable amounts of materials must be transported to these construction sites; they may be supplied by rail, truck, or marine vessel. The increased transport of materials produces an increment in emissions, noise, and risks along the various transportation routes. Impacts associated with these transportation modes as discussed in Section 3.3.5 may be applicable.

As with most elements of the oil industry, major potential impacts are related to oil spills and chronic leaks. Major spills can occur from offshore oil wells, but the impacts of such a spill on the Columbia River Estuary will most likely be minimal. For there to be an impact, the oil spill would have to have an onshore trajectory and make landfall near the mouth of the estuary. In the ocean, containment and recovery of the spilled oil is probably not feasible for most wind, wave, and current conditions. Contingency plans should focus on preventing spilled oil from entering the estuary, with the entrance breach being the most likely place to attempt blocking passage. The seasonal variability in the movement of the Columbia River plume in the Pacific as presented in the CPCR Vol. 2, Figure 2-19, indicates that offshore spills are more likely to come onshore in the winter.

3.3.5.2.3 Ecosystem perspective. Impacts associated with OCS development have largely been discussed in Sections 3.2.1, 3.3.2, and 3.3.5, and relate to ongoing construction associated with support activities, transportation, and oil spills. The former two categories of impacts can be largely contained with best available control technology, while the latter represents a common hazard of all oil operations. The primary pathways of concern probably lead through the aquatic communities of the estuary, either through accidental spill or uncontrolled runoff of toxic materials and sediment, or by fill of wetlands for marine support bases.

CHAPTER 4.0 ECOSYSTEM MODELING OF ENERGY RELATED DEVELOPMENTS

4.1 INTRODUCTION

The ecosystem in An Ecological Characterization of the Pacific Northwest Coastal Region (CPCR) and this study portray interactions between physical processes, biological communities, and human activities as they relate to energy developments.

The modeling methodology used was developed and described in detail in Volume I of the CPCR. The models are arranged uniformly so that within an ecosystem, the physical processes are presented on the left side, biological processes in the middle, and socioeconomic activities on the right (see Figure 4.1). Natural inputs and outputs to the ecosystem interface from the left, and socioeconomic inputs and outputs interface mostly from the right. The symbols used are mostly based on Odum (1971, 1972); the Glossary of Symbols from the CPCR is also reproduced here.

The models presented in this chapter include: riverine, estuarine, channel, sandflat, mudflat, emergent vegetation, and riparian habitats. The impacts on the riparian habitat are most diverse, depending on the types of energy development. Consequently, the riparian model is presented first without energy related developments, and then with energy related developments in the following order: riparian-hydroelectric, riparian-thermoelectric, riparian-processing facilities, riparian-LNG, riparian-transportation/transshipment, riparian-transmission lines/pipelines, riparian-extraction facilities, and riparian-OCS support.

Tables 4-1 through 4-7 provide summaries of habitat specific impacts of energy developments, covering hydropower (4-1), thermal power/processing (4-2), LNG (4-3), transportation/transshipment (4-4), transmission lines/pipelines (4-5), extraction operations (4-6), and OCS support (4-7).

Habitat food webs presented in the CPCR Vol. 3, provide a better definition of the biological community composition than the ecosystem models, but are generalized for habitat types and may still vary between locations within the Columbia River or its estuary.

For a specific site, the habitat models in this chapter, the habitat food webs in the CPCR, and the community composition combined, may help to distinguish the biological aspects of a site important to a species. Sites may be important for reproduction, food, shelter, or protection.

Additionally, habitats depend on inputs from and interactions with different, adjacent habitats. Construction, operation, and hazard related impacts extending to these adjacent habitats may be more significant than site-specific impacts.

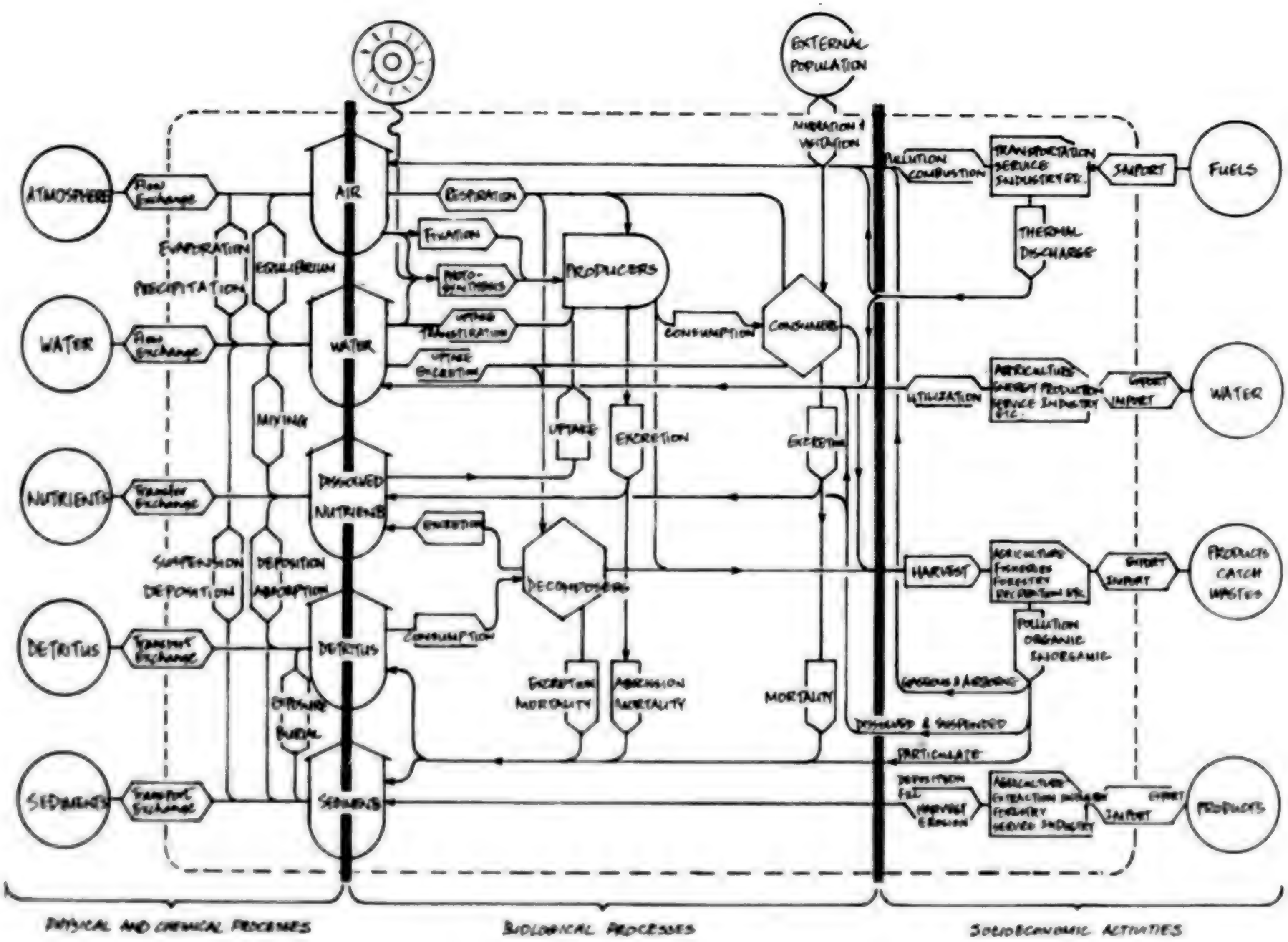

Figure 4.1. Complex general ecosystem model.

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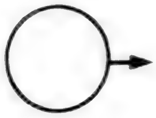
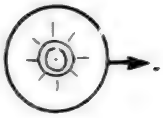
Figure 4.1. Continued.

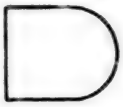
GLOSSARY OF SYMBOLS



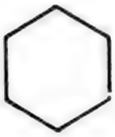
SOURCE OF ENERGY OR MATTER external to the system or portion of a system being modeled. This symbol and many of the others here are based on H.T. Odum (1971 and 1972).



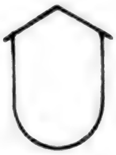
SOLAR RADIATION. The central figure, which is used for the sun in pictorial diagrams, is taken directly from a pteroglyph left by Pacific Northwest Coastal Indians (Meade 1971).



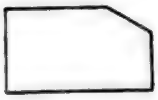
PRODUCER: plant, or plant community. For thermodynamic balance, H.T. Odum (1971 and 1972) often shows heat sinks in connection with this and other symbols. Heat sinks are not used for the qualitative ecosystem diagrams in this report.



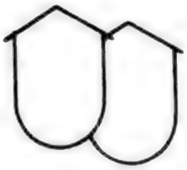
CONVERTER: animal, microbe, or community of animals or microbes; can be consumers or decomposers or both.



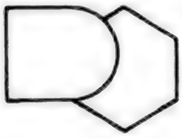
STORAGE COMPARTMENT OR SUBSTRATE.



SOCIOECONOMIC ACTIVITY. Used, with labels, to cover the whole range of human activities except for the strictly biological, such as eating.



MULTI-COMPARTMENT STORAGE.



BIOLOGICAL COMMUNITY: producers and converters. The boundary between the compartments may be omitted, and their relative positions may vary. Converters may sometimes be presented separately as consumers and decomposers, and sizes of all three components may vary to show relative significance within the particular biological community.

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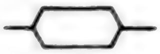
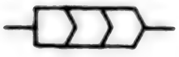
Figure 4.1. Continued.

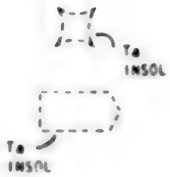
GLOSSARY OF SYMBOLS (continued)



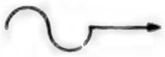
TWO-WAY VALVE. Flow in tow directions along a single path occurs through and is controlled by a primary regulating process and its secondary regulating factors. Flow can go either or both directions, e.g., materials in and out. This symbol often represents a complex group of interacting processes.



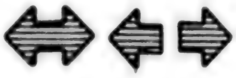
SEQUENTIAL VALVE. Flow occurs through and is regulated by a series of primary regulating processes acting in sequence with little or no interaction. (Previous two valves are used for non-sequential or complex interacting processes.)



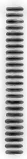
SECONDARY REGULATING FACTOR. The controlling factors that regulate a primary regulating process (represented by either a switch or a valve, as above). Examples illustrated here represent the regulating factors air temperature (Ta) and insolation (INSOL).



CYCLICAL OR PERIODIC FLOW FROM SOURCE, such as tides, daily and seasonal cycles of the sun, etc.



GAIN AND/OR LOSS OF HABITAT. When not otherwise labeled, the arrow applies to the regulating (or process) value by which it is placed. The arrow points out of the habitat boundary (dotted line enclosing the habitat) for loss, into the boundary for gain.



BOUNDARY BETWEEN ECOSYSTEM MODEL COMPARTMENTS (PHYSICAL-CHEMICAL, BIOLOGICAL, SOCIOECONOMIC).

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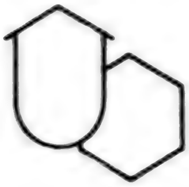
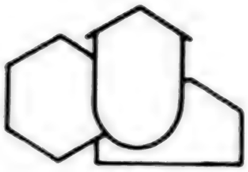
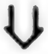
GLOSSARY OF SYMBOLS Figure 4.1. Concluded.



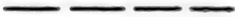
SUBSTRATE-CONVERTER COMBINATION, such as the detritus-decomposer union, where the distinction between the two is not essential for the system being modeled.



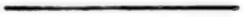
COMPOSITE HUMAN COMMUNITY AND ACTIVITY; a combination of conversion, storage, and socioeconomic functions.



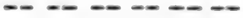
TO DETRITUS. Indicates a flow of material and energy to the nonliving compartment. Combines mortality and flow to detritus, thus simplifying models.



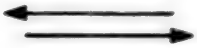
BOUNDARY for the specific ecological unit being modeled.



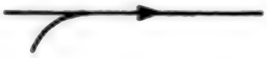
FLOW PATH FOR ENERGY OR MATTER OR DOLLARS.



FLOW PATH FOR REGULATING INFLUENCE OR EFFECT (i.e. not flow of energy, matter, or dollars).

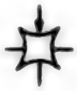


DIRECTIONAL FLOWS.

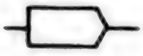


CONVERGING OR COMBINING FLOWS.

DIVERGING OR BRANCHING FLOWS.



SWITCH. Incoming flow is divided into two or more different paths by a primary regulating process, or goes one way or another depending on the regulating process and its secondary regulating factors.



ONE-WAY VALVE. Flow in one direction along a single path occurs through and is controlled by a primary regulating process, and depends on its secondary regulating factors.

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Table 4-1. Environmental impacts of hydroelectric power dams during construction and operation.

	Project phase	
Habitats	Construction	Operation
Estuarine		
Water column	Increased turbidity Decreased flow downstream during reservoir filling	Barrier to fish migration, loss of local fishery Reduced seasonal and storm-related peak flows, short-term flow fluctuations Increased water temperature
Subtidal, intertidal, and emergent vegetation	Increased sedimentation	Power peaking flow regulation acts in conjunction with the tides to cover and uncover the "intertidal" areas
Riparian		Downstream flood control readiness upland river interaction, ultimately reducing riparian habitat and species dependent on this habitat
Riverine		
Water column	Increased turbidity Decreased flow downstream during reservoir filling Creation of lacustrine habitat	Supersaturation of dissolved gases may kill fish Fish passing through turbines are stunned, injured, vulnerable to predators Regulate flow, reduction of dissolved O_2 Impoundment leads to temperature increases; diversion dams may eliminate flows for stretches of the river Barrier to fish passage, fish mortalities Loss of flow (where diverted to other uses)
River Bottom	Increased sedimentation Loss of spawning habitat for salmon or steelhead	Sedimentation in reservoir, armouring, loss of gravel recruitment
Riparian	Increase erosion, reduced slope stability Inundation of upstream riparian habitat Blockage of animal migrations Loss of wintering habitat by reservoir filling	Decreased flooding which leads to: loss of riparian habitat increased human encroachment

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Table 4-2. Environmental impacts of thermal-electric and processing facilities during construction and operation.

	Project phase	
Habitats	Construction	Operation
Estuarine		
Water colum (channel)	None[a]	Increased water temperature Increased waste loading but regulated under NPDES System Increased vessel traffic to supply or service the facility Accidental spills of contaminants
Subtidal intertidal, and emergent vegetation	None[a]	Stirring the bottom sediments in and near channels by vessel traffic Incorporation into sediments and food web of pollutants discharged from facility Waterfowl may be killed or injured by spilled oil
Riparian	None[a]	None[a]
Riverine		
Water column and channel	Increased turbidity from: 1) runoff at site 2) shoreline alterations 3) dredging to install water intakes or discharge pipes Creation of piling habitat if a marine terminal (Table 4-5)	Increased water temperature Treated waste discharges (NPDES permit) Entrainment of plankton (and maybe fish) in water intakes Low-level radiation (nuclear power) Loss of water (evaporation)
Emergent Vegetation	Loss of habitat from construction and fill activities	Small, but chronic releases of toxic substances may be concentrated within this habitat, resulting in biological stress and gradual changes Releases of treated wastes via outfall should be more dispersed to have little effect
Riparian	Loss of habitat, and organisms from clearing and site construction Transmission line or pipeline right-of-ways and other upland transportation impacts as well	Stack emissions, acid rain, salt drift operational disturbances to wildlife: trains, noise, etc.

[a] All proposed sites are in the Lower Columbia River and not the estuary

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Table 4-3. Environmental impacts of LNG facilities and operations, including marine vessel traffic.

Habitats	Project phase	
	Construction	Operation
Estuarine		
Water column and channel	None[a]	Marine vessel traffic
Intertidal and emergent vegetation	None[a]	None[a]
Riparian	None[a]	None[a]
Riverine		
Water column and channel	Turbidity from dredging at terminal site--if needed	Water intake may entrain and kill plankton and small fish Water temperature would increase; in event of LNG spill, water could become excessively chilled
Emergent/Vegetation	Loss of habitat from construction and filling Species avoidance during construction	None[a] Species that avoided the site during construction might return as operation of LNG facility becomes passive
Riparian	Loss of habitat from clearing and building Direct mortality to slow moving organisms	None Operation passive

[a] Proposed site not in the estuary

Table 4-4. Environmental impacts of transportation and transshipments during construction and operation.

Habitats	Project phase	
	Construction	Operation
Estuarine		
Sub-tidal (e.g., channels)	Configuration changes attributable dredging Creation of piling habitat Turbidity increases during dredging Water quality may be degraded	Continuous use for shipping, barging & maintenance dredging may limit use by wildlife and alter benthos
Subtidal/intertidal (e.g., sand & mud flats)	SAND FLAT: Some grading & filling may be required in this habitat	No additional impacts although effluents may contaminate some flats
	MUD FLAT: Suffocation of epibenthic algae & filter feeding invertebrates from dredging & filling Loss of feeding habitat for wading birds Creation of piling habitats	Phytoplankton disturbance from shipping and barging may decrease productivity Prop wash of shipping will stir up sediments at berthing facilities, release toxics over long periods
Intertidal and emergent vegetation	Filling of marsh & suffocation of vegetation Loss of small mammal habitat Loss of waterfowl nesting/feeding area	Effluents and runoff may be toxic to halophytic and herbaceous vegetation
Riparian	Loss of amphibians & their habitats Destruction of mustellid, microtene, insectivore, mammal habitat	Maintenance dredging will continue to inhibit vegetative growth

(continued)

Figure 4.4. (Concluded).

Habitats	Project phase Construction	Operation
Riverine Rivers	Deepening & widening of channel will increase turbidity & influence water flow & quality Reduction of phytoplankton & periphyton activity Creation of piling habitat	Minor impacts attributed to shipping
Intertidal and emergent vegetation	Dredging & shoreline stabilization &/or fill will reduce at site vegetation Loss of benthic invertebrates at dredging location & possibly at some adjacent areas Loss of small mammal & waterfowl breeding, nesting, & feeding areas	Prop wash will stir sediments, release toxics Effluents & runoff from site may be toxic to vegetation Small but chronic quantities of ship fuels will be released or escape
Riparian	Loss of amphibians & their habitats Destruction of mustellid, microtene & insectivore habitats Suffocation & injury to willow, alder, ash, cottonwood & shrubs from site preparation	Operational disturbance to wildlife from loading/unloading machinery & rail traffic

Table 4-5. Environmental impacts from electrical transmission lines and pipelines during construction and operation.

	Project phase	
Habitats	Construction	Operation
Estuarine		
Water column and channel	Minimal for river crossings If buried crossing, turbidity If right-of-way near, estuary may get increased sedimentation	Flying birds may strike wires and die; Herbicides used in ROW maintenance enter water column
Subtidal/Intertidal and emergent vegetation	If buried crossing, then localized dredging impacts	Bird collisions; Herbicies in ROW maintenance enter bottom sediments
Riparian	Transmission towers and access roads will remove some land from productivity ROW will revert upland to early succession stage	ROW maintenance activities to keep upland at each succession stage Use of herbicides
Riverine		
Water column and channel	(same as estuarine)	(same as estuarine)
Emergent Vegetation	(same as estuarine)	(same as estuarine)
Riparian	(same as estuarine)	(same as estuarine)

Table 4-6. Environmental impacts of oil and gas extraction during construction and operations[a].

Habitats	Project phase Construction	 Operation
Estuarine		
Water column and channel	None	None
Subtidal/Intertidal and emergent vegetation	None	None
Riparian	None	None
Riverine		
Water column and channel	Pollution from drilling muds Increased erosion from sites and access roads may enter water	Minimal
Intertidal and emergent vegetation	Runoff may carry toxins from drilling muds and sediment from erosion to these habitats where they may be deposited and be available for biological uptake	Minimal
Riparian	Minor clearing for access roads, drill platforms, pipeline right-of-ways, and storage and pumping facilities Noise will lead to avoidance by some species	Once development completed, extraction proceeds relatively passively

[a] Sites of anticipated development do not border the estuary

Table 4-7. Environmental impacts of OCS oil and gas support bases.[a]

Habitats	Project phase	
	Construction	Operation
Estuarine		
Water Column and channels	Increased turbidity because of dredging Creation of piling habitat	Increased vessel traffic (work boats) Water consumption (rig fabrication facility)
Subtidal/Intertidal and emergent vegetation	Dredge and fill impacts alternation of habitat to less productive form Creation of piling habitat	None
Riparian/Upland	Clearing, filling, loss of habitat RR access	Noise, RR and truck deliveries
Riverine	None	None

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[a] No OCS oil and gas development support will occur in the Lower River

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The CREDDP research data will help to identify important food source species for other species of concern. It is unlikely that it will define the significant differences (if any) of pollutant uptake, bioaccumulation, and food chain magnification affecting species of concern for discharges and spills of the wide range of materials associated with energy facilities.

Pollutants are modeled here as entering the air, water, and sediment of the habitat, and thus becoming available for biological uptake or exposure. The direct impingement of a pollutant onto a species of concern is not regarded as an important pathway.

An energy facility may present direct hazards to fish and wildlife, such as a fire or explosion. The hazards may also be indirect, as with a major pollutant spill. Within the modeling, hazards are often treated simply as ecosystem risks, and the reader is referred to the appropriate energy facility discussion in Chapter 3.

The conceptual modeling does not address behavioral aspects of fish and wildlife in respect to energy developments. The CREDDP biophysical interactions group was working with Hypothesis Systems Models (HSM's) which emphasized behavioral aspects of some species of concern (such as salmon). Preliminary ecosystem modeling for CREDDP used modified Forester symbols, which are considerably different from the modified Odum symbols used in this report and in the CPCR.

Conceptual modeling is a tool to aid in understanding how a system works. The adequacy of the models is largely based on the needs and knowledge of its users. These models are intended to be of general assistance in management decisions by a combination of technical and nontechnical persons. Many relationships are generalized, but provide a basis from which treatment of specific factors is possible.

4.2 RIVERINE ECOSYSTEM MODEL

The Riverine habitat in the Western Hemlock Zone is generally characterized by cold, clear waters generally low in nutrients. While this description holds for the tributaries to the lower Columbia River, the river itself is more turbid and warmer because it drains an extensive inland area and is warmed while stored in the numerous reservoirs upstream of the study area.

The Columbia River is the largest river on the west coast of North America, and is used for power generation, irrigation, transportation, and fisheries. The greatest impacts on the lower Columbia River have resulted from main stem dams above the study area, which have altered the flow regime (both seasonally and daily), increased water temperatures, and posed physical barriers or hazards to upstream and downstream migration of anadromous fish.

Transportation requirements for major ports along the Columbia River, have led to a program of maintenance dredging by the U.S. Army Corps of Engineers. Maintenance dredging escalated in 1980, after the channel was blocked by sediments delivered by the Cowlitz River from the Mt. St. Helens eruption.

Commercial and sport fishing within the river is particularly favored for salmon, steelhead, and sturgeon. Waterfowl concentrations occur, and duck hunting is a major sport activity. Logging is the primary regional activity, and the river is used for log storage, log shipping (by marine vessels for export, and by tug and raft techniques for regional use), lumber, pulp, and paper industries. The major existing energy developments along the river include the Trojan Nuclear Power Plant at river mile 72, and the gas or oil fired generating facility at Beaver (river mile 53). Hydroelectric dams occur upstream of the study area and on the Cowlitz and Lewis tributaries. Major population centers bordering the lower Columbia River are Longview, WA (river mile 65) and the Portland-Vancouver area (river mile 105).

Tributaries to the estuary and lower Columbia River provide important fish habitat, domestic water supplies, and recreational values. Some offer potential for small hydropower. These tributaries include the Cowlitz and Lewis rivers, in Washington (which include Mt. St. Helens in the drainage basins) and the Willamette in Oregon, which joins the Columbia at Portland. The tributaries to the estuary are smaller by comparison, and include the Skipanon, Lewis and Clark, Youngs, John Day, Big Creek, Bear Creek, Hunt Creek, Grant Creek-Blind Slough, and Plympton Creek in Oregon. The Washington tributaries to the estuary include the Grays River, the Deep River, Skamokawa Creek, Alder Creek, Wallacut River, Elochoman River, and Chinook River.

The riverine ecosystem model is presented in Figure 4.2 and is modified from the riverine model in the CPCR to emphasize energy development impacts on the system. Major components, processes, and relationships of the riverine ecosystem and energy related developments are modeled and discussed in detail in the following subsections. These are noted in the model by the given numerals. The water column (1) including the processes and constituents is discussed first, followed by information on the substrate (2) and community composition (3). The community is adapted to the physical conditions of the water and substrate and the perturbations imposed by human activities. Human activities will draw on the water supplies of the river or the groundwater (4), impounding the flow behind dams (5) to harness the potential energy and withdrawing cooling water (6) for thermal energy generation or fuel processing. Impounded water is heated by the sun and then discharged (7) to continue its downhill flow. Water used for cooling purposes is also discharged (7) to the river again, also with an increased heat content. The use of river water for cooling and its impoundment result in losses of water from the system by evaporation. Water is also used for various processes within energy facilities (8). Municipal uses (9) and the pulp and lumber industries (10), produce wastes (11) which are discharged back to the river after treatment (12)

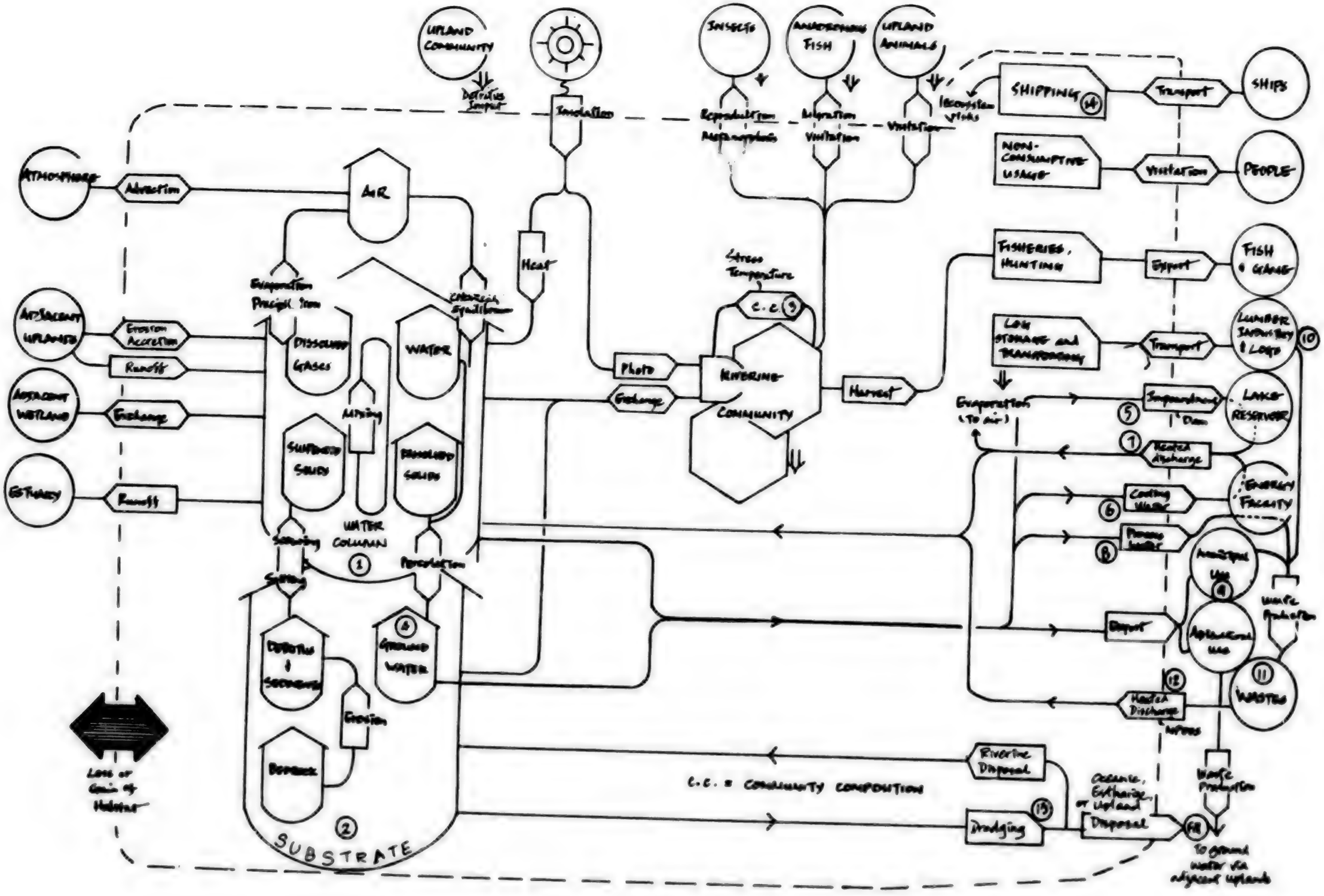

Figure 4.2. Riverine ecosystem model.

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under state enforced National Pollution Discharge Elimination System (NPDES) permits. Dredging (13) activities to support shipping (14) are discussed, followed finally by ecosystem risks associated with energy facilities.

4.2.1 Rive[illegible] [illegible]r Column (1)

The riv[illegible]e water column is dynamic, driven downhill by gravity, and supplied by d[illegible]t precipitaton, groundwater, snow melt, and other runoff. The natural flow is regulated by upstream dams, which reduce the peak flows resulting from spring freshets and floods and increase the winter and summer flows to meet increased electrical demand. Small, additional decreases can occur through losses to groundwater, evaporation, and uptake by various human activities, although the latter may return some of the water to the river bearing a waste load or increased temperature. These processes of the hydrologic cycle are modeled in detail in Section 2.4 of the CPCR, Vol 1.

Flood data for the Columbia River at Vancouver and Portland are presented in the CPCR Vol. 4, Section 1.2.3 of Watershed Unit 3. The height and duration of flooding has decreased with the construction of the main stem dams, and this has resulted in a mixed impact. Flooding of the river may be viewed as an interaction between the river and the adjacent land. Indeed, this infrequent event is one factor which distinguished the riparian habitat from other terrestrial habitats. The dams on the Columbia River have reduced flooding, thereby causing a long-term reduction in the amount of riparian habitat. This, in turn, has had a gradual effect on organisms dependent on the riparian habitat and has permitted humans to construct structures in places where formerly they would have been vulnerable to floods. Human presence then further alters both riparian and riverine habitats. In summary, while dams have greatly reduced certain impacts of flooding on riparian habitats, they have limited the operation of the very processes which creates that habitat, and have also created the possibility of floods of far greater magnitude than before, should they fail.

Envirosphere (1980) evaluated water quality in the estuary for the CREDDP and conducted studies in the lower river and estuary to evaluate changes in water quality resulting from the Mt. St. Helens eruption. Envirosphere's water quality literature review presented parameters and ranges observed for a station at Bradwood (river mile 39) from 1973 to 1978, and compared them with data from 1961 for a station at river mile 54. Envirosphere noted that the ranges abstracted from the USGS data at Bradwood for temperature, pH, alkalinity, dissolved oxygen, and total solids are very similar to the ranges reported by Sylvester and Carlson (1961) (river mile 54), indicating no significant changes. The nitrate ranges, however, showed a noticeable increase, while the ammonia ranges showed a decrease over time. The water quality parameters from the Bradwood USGS station for 1973 to 1978 reported by Envirosphere (1980) are presented in Table 4-8. Additional data presented by Envirosphere indicated that nutrient levels and fecal coliform levels above the Portland-Longview area are significantly lower than below this area, indicating that

Table 4-8. Water quality measurements at the USGS Bradwood, Oregon water quality monitoring station.

Measurement	Unit	Range
Temperature	°C	2.5-22.5
pH	Units	6.4-8.4
Dissolved oxygen	mg/l	7.3-14.3
Conductivity	_mho/cm	100-228
Dissolved silica	mg/l SiO_2	3.6-15
Total $NO_2 + NO_3$	mg/l N	0.00-0.78
Total ammonia	mg/l N	0.00-0.13
Total organic nitrogen	mg/l N	0.00-1.10
Total nitrogen	mg/l N	0.09-1.20
Total phosphorus	mg/l P	0.01-1.60
Total organic carbon	mg/l	1.8-4.4
Dissolved solids (at 180°C)	mg/l	62-118
Total arsenic	mg/l	0-4
Cadmium	_g/l	0-10
Chromium	_g/l	0-40
Copper	_g/l	<10-290
Iron	mg/l	0.03-1.90
Lead	_g/l	2-34
Zinc	_g/l	10-220
Selenium	_g/l	0-3
Mercury	_g/l	0.0-1.1
Calcium	mg/l	11-23
Magnesium	mg/l	2.0-8.1
Sodium	mg/l	1.8-8.7
Potassium	mg/l	0.4-2.1
Alkalinity	mg/l $CaCO_3$	39-65
Dissolved sulfate	mg/l SO_4	3.4-17
Dissolved chloride	mg/l Cl	1.3-6.7
Oil and grease	mg/l	0-7
Fecal coliforms	cols/100 ml	12-8500
Fecal streptococci	cols/100 ml	2-8650
Chlorophyll *a*, phytoplankton	_g/l	0.0-40.0
Chlorophyll *b*, phytoplankton	_g/l	0.0-7.8
Chemical oxygen demand	mg/l	2-28

Source: Envirosphere (1980).

[a] All metal values reported are total recoverable unless otherwise noted.

waste loading from those population centers is occurring. Figure 4.3 presents the monthly average temperatures and chemical concentrations (phosphate, nitrate, pH, alkalinity, total CO_2, dissolved oxygen, and dissolved oxygen saturation), of the Columbia River water entering the estuary (at zero salinity). These data represent the river's impacts to the estuary and describe the river's chemical parameters. Summer is characterized by high temperatures, decreased nutrients (with nitrate being limiting for spring and summer), and dissolved oxygen saturation greater than 100 percent during the spring and summer, which may be indicative of increased plant productivity, turbulent mixing, and elevated temperatures (which lower the saturation level of the water). The lowest dissolved oxygen was observed in October, with saturation levels of about 80 percent.

The water sampling following Mt. St. Helens eruption determined that impacts on water quality appeared to be transitory and relatively insignificant (Envirosphere 1980). Temporary turbidity increases downstream from the Cowlitz River were noted.

The regional climate affects the water column by solar insolation, evaporation, precipitation, and temperature, which act individually and synergistically to produce adjustments in water characteristics and river flow. Envirosphere (1980) determined that the possible solar insolation varied from extremes of about 1,000 langleys per day in late June to about 250 langleys per day in late December. Cloud cover reduces these maximum values so that long-term mean daily solar radiation data based on 30 years of record varied from 70 langleys per day for December to 550 langleys per day for July in Portland, with similar values in Astoria. Figure 4.4 presents average monthly solar radiation (langleys/day) at Astoria and Portland.

Precipitation over the lower Columbia River averages about 80 inches a year near the estuary, decreasing to about 40 inches a year at Portland. The precipitation increases again with elevation in the coastal mountains, which drain to the lower river and estuary. Evaporative losses are not as well documented, but values of 25 to 30 inches per year have been reported from surface waters in the region (CPCR Vol. 2, Section 2.4).

4.2.2 Substrate (2)

Sediments and detritus continuously settle out and are resuspended, but a net downhill flow to the estuary occurs (see Sediment Transport model in the CPCR Vol. 1, Section 2.5.4). In steeper gradients, sediments are quite coarse, and erosion of the actual bedrock may even occur (within the study area this is only applicable to some of the tributaries). Groundwater will move to, or from, the adjacent aquifers depending on variations in hydraulic head.

Sediment transport in the lower Columbia River and Estuary up to river mile 46 (the eastern end of Puget Island) is under study by the University of Washington, under the CREDDP. Most sediments in the Columbia River are inorganic sands, silts, and clays. The upstream dams have reduced the total amount of sediment discharge by the river, but reduced peak flows have probably permitted greater deposition. Movement of sediment is greatest within the river during spring freshets when river flow is greatest.

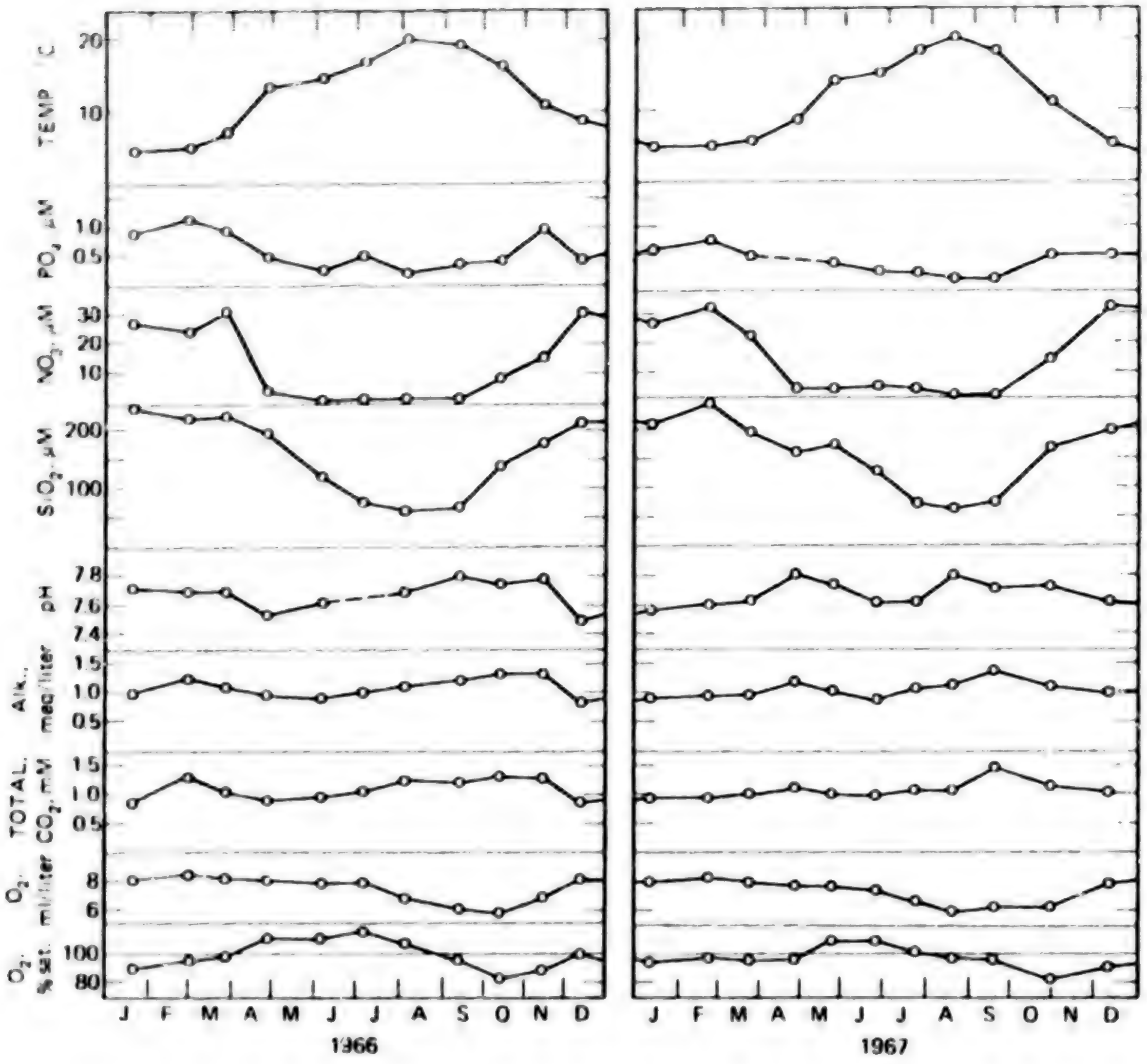

Figure 4.3. Monthly average water temperatures and chemical concentrations of the Columbia River water entering the estuary at zero salinity (Park, Osterberg, and Forster 1972).

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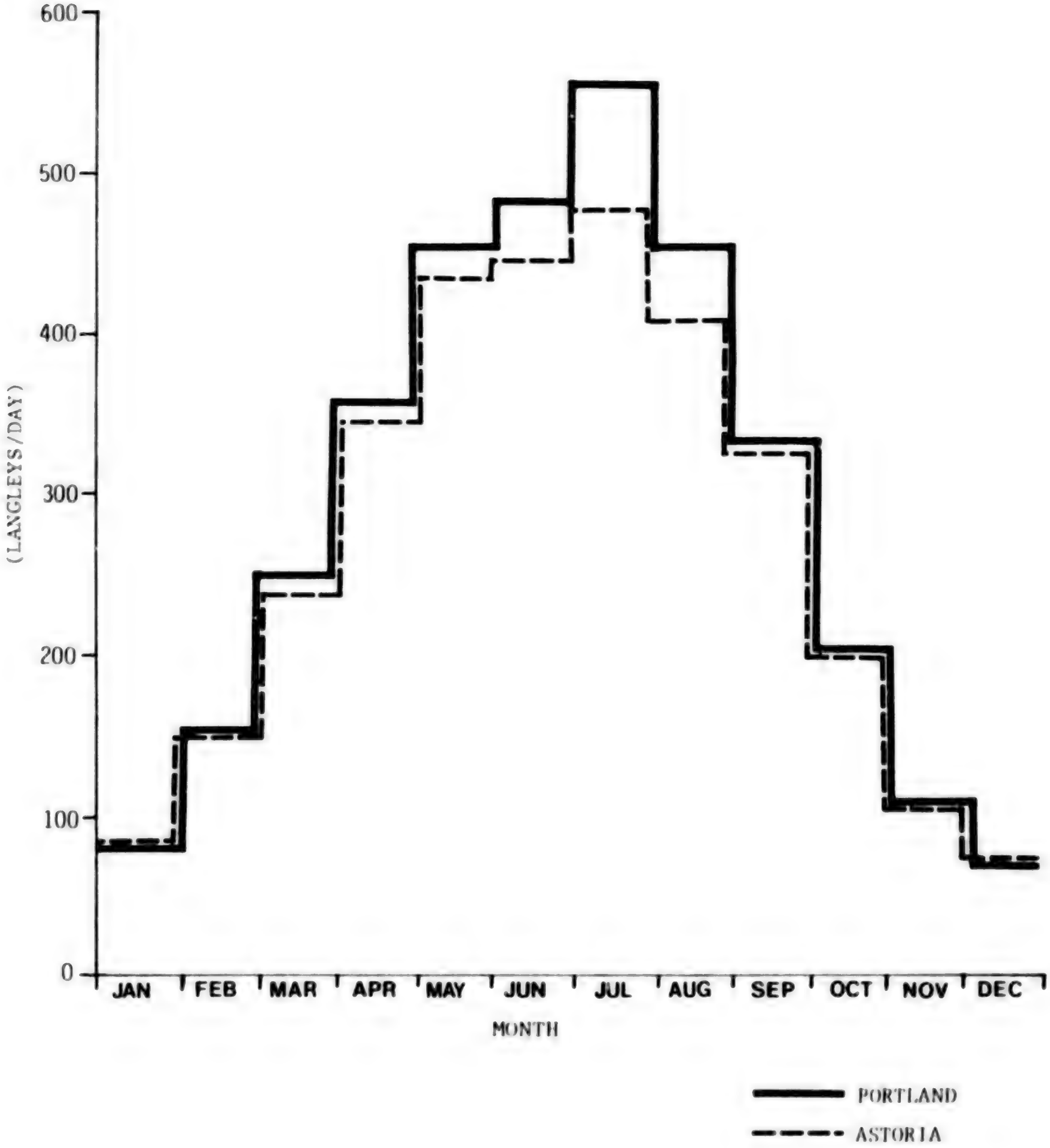

Figure 4.4. Average monthly solar radiation (langsleys/day) at Astoria and Portland, Oregon for the combined years 1941-70 (Envirosphere 1980).

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Descriptions of suspended and bottom sediment transport in the river are presented by Seaman (1977) based on various methods of the U.S. Army Corps of Engineers and the USGS. Seaman (1977) acknowledges that the methods of evaluation are not precise, but do provide useful approximations. The USGS estimated coarse sediment transport of 2.3 million tons for the Columbia River at Vancouver during the water year 1963 (water years run October 1 to September 30). For the same period, the USGS estimated suspended sediment transport of 6.1 million tons.

Sedimentation in the lower Columbia River and Estuary is a natural process, but is altered by human activities such as dredging and construction of jetties. Dredging is discussed in note #13, Section 4.2.6, and in Chapter 3, Section 3.3.4.1.

4.2.3 Community Composition (3)

Perhaps the species of most concern to the public and to USFWS are the anadromous fish. Commercially they are the most significant and the most impacted by hydropower and other developments influencing water characteristics. Detailed discussions of species of concern as directed by USFWS are presented in Chapter 5.

The community composition for the riverine habitat is presented in Appendix A. (Although the community composition for the riverine/Western Hemlock Zone habitat was not presented within the CPCR Vol. 3 because of space limitations, it was prepared for the USFWS as a computer printout.) The species list for the riverine/Western Hemlock Zone was obtained from the USFWS and was edited to prepare a community composition specific to the Columbia River. (Note: this was also done for the riparian/Western Hemlock Zone, but was not done for any of the other habitats, as community compositions were presented within the CPCR.)

4.2.4 Water Uses

This section discusses water uses as they relate to the model, specifically, water withdrawal (4), impoundment (5), cooling water (6), and release/discharge (7).

Water is withdrawn from the river or temporarily halted in its downhill flow by human activities. Dams impound (5) the water creating lacustrine habitats in place of riverine and upland habitats, and hindering the passage of anadromous and other fish. Diversion dams have minimal impoundment, achieving their hydraulic head by a large vertical drop between the dam and the powerhouse, connected by either pipelines or tunnels. Diversion dams also can isolate fish communities if the river flow is completely halted between the dam and the powerhouse. Diversion dams do not occur on the main stem, but some may be developed in Grays River and Big Creek, tributaries to the lower Columbia River and estuary.

The impacts on anadromous fish from impoundment reservoirs on the Columbia River and its tributaries result from physical barriers, hazards of migration, and alterations of river flows. Impoundment from upstream main stem dams has significantly increased the water temperatures in the lower river and significantly depleted the volume of the spring freshet, with resulting impacts on fisheries (USEPA et al. 1971). The timing and relative abundance of adult anadromous fish migrations indicate some avoidance behavior at temperatures above 70°F (21°C) (USEPA et al. 1971). Thermo electric generating and processing facilities will withdraw water for cooling purposes, the most significant facility on the lower Columbia being the Trojan Nuclear Power Plant at river mile 72.

4.2.5 Process Water

The following subsection discusses water processing as it relates to the riverine model, specifically, water withdrawal (Figure 4.2, River Ecosystem Model), energy facilities process use (8) municipal use (9), nonenergy facilities process use (10), waste production (11), and discharge (12).

Process water is that water used in combination with raw fuel materials or chemicals to manufacture or refine a product. Process water acquires a load of toxic materials and requires storage and treatment before it may be safely returned to the environment. Contaminants include spent sulfite liquor from the pulp and paper industry, refinery wastes, scrubber sludge wastes from coal or oil fired facilities, runoff from dust suppression systems at coal terminals, slurry water from coal slurry delivered by pipeline to a terminal, and other sources. All require treatment before they can be safely discharged. Treatment and discharge are regulated under the NPDES administered by state departments in both Washington and Oregon (see Chapter 7). Municipal uses of river water also produce a significant waste load which must be treated. Seaman (1977) and Envirosphere (1980) describe waste discharge in the lower Columbia River and Estuary.

The river or groundwater may also be affected by residences in low density areas where septic tanks are used instead of sewage treatment. While septic tanks do constitute a form of treatment, seepage into groundwater and the river does occur and is a nonpoint source of wasteloading to the system.

4.2.6 Dredging (13) and Shipping (14)

Dredging permits the continued navigation of the river by marine vessels, a partially energy related function. Dredging impacts arise from physically removing sediment and benthic organisms at one site, and depositing them in another. Impacts to water quality are described in Section 3.3.4.1. If the sediments are contaminated by oils or toxic materials, then dredging may facilitate the releases of the contaminants to the water column.

Increased shipping has little significant impact on the riverine habitat, provided no accidents occur. Oil spills may occur related to shipping. However, due to the tremendous flow of water through the system, these should not significantly impact the water column itself. The impacts of large spills are discussed in the following section and Section 3.3.2.1.

4.2.7 Hazards (15)

Shipping activities in the Columbia River occur in support of energy facilities (refineries, coal transshipment, OCS support, and LNG developments). Each additional facility or expansion of an existing one increases the number of ships. Some cargos are hazardous to the river and estuary downstream, and increases in number of ships or in the volumes of hazardous cargos increase the risks to the ecosystems. Cargo spills are serious and can result during groundings, handling at the docks, or from collisions, fires, or explosions, either at the docks or in the shipping channel. Moving with currents, major oil spills will enter the water column and the substrate. Oil in the environment could impact the biological community at, and downstream from, the spill site. The dynamic nature of the river makes containment difficult, but also helps the affected areas to clean themselves. Other cargos vary in their toxicity. LNG or LPG shipments pose additonal risks to the ecosystem, in that a spill would extract considerable heat from the river as the LNG or LPG evaporated, after which a fire or explosion may result. The gas cloud would move with prevailing winds, following the elevation contours; hence, sites upstream of the vessel accident could be affected also.

Toxic substances may enter the river through failure of an adjacent energy facility. A hazardous impact from a hydro facility would result if the structure of the dam itself failed. Such an event could be produced by earthquakes, sabotage, or war. The sudden release of large volumes of water would be devastating on the organisms within the existing riverine and the downstream estuarine habitats. These hazards are not illustrated in the model.

4.3 ESTUARINE ECOSYSTEM MODEL

The estuarine habitat extends from the river mouth to one or two miles upstream of Harrington Point (Neal 1972), using salinity as a basis for defining the estuary. The CREDDP, however, extended their study boundaries to the eastern tip of Puget Island (river mile 46), which is actually lower river. Approximate boundaries within the estuary were determined from CREDDP for marine, mixing, and freshwater zones, with the riverine zone essentially occupying the lower river. The marine zone is defined by a salinity of 10 parts per thousand (ppt), or higher, the mixing zone by a salinity of 0.05-10 ppt, and the freshwater zone (lower river) as having a salinity of less than 0.05 ppt. The boundaries between these zones are not fixed, but vary with tidal conditions, changes in atmospheric pressure, and changes in runoff. The changes in runoff are the most influential and produce seasonal shifts of the general zonal boundaries. During winter and spring, high freshwater outflow minimizes the marine influence on the lower estuary. The mixing zone is located in the lower bays and may extend into the ocean during high flow. Much of the lower estuary at this time has a mixing zone community, while the upper estuary maintains a freshwater community. From summer through fall, reduced freshwater flow into the estuary results in the marine influence extending farther upriver, while the mixing zone extends into the upper estuary, with corresponding changes in the plankton community (Envirosphere 1980).

The Columbia River Estuary is not ringed with industrial development, nor is the upland heavily populated. Rather, the population and industry is mostly concentrated upstream along the Columbia River. Commercial traffic passes through the estuary, and waste products will flow downstream to enter the estuary. The principal human uses of the estuary are shipping and fishing (both commercial and sport). The principal human impacts on this estuarine ecosystem arise from upstream flow regulation by main stem dams, channel dredging and maintenance, fishing pressures (past and present), and fisheries management decisions (such as increased hatcheries).

Estuarine habitats include channels, mudflats and sandflats (subtidal and intertidal), pilings, rocky substrate, and emergent vegetation. Channels, mudflats, sandflats, and emergent vegetation are modeled in this chapter as specific habitats within the estuarine ecosystem, with emphasis on the impacts of energy developments on these habitats.

Figure 4.5 presents the estuarine ecosystem model. Its major components are dicussed in the following subsections and are noted in the model by the given numerals: air/climate (1), river flow (2), ocean exchanges (3), tides (4), mixing/circulation (5), water column (6), sedimentation (7), sediments (8), insolation (9), productivity (10), community compositions (11-14), log storage (15), harvest (16), dredging (17), industry development (18), shipping (19), and discharges and spills (20).

4.3.1 Air/Climate (1)

The climate of the estuary is typical of the Pacific Northwest Coastal Region as described in the CPCR Vol. 2 Section 2.3. Rainfall averages about 80 inches a year, with about 200 days a year receiving 0.1 inch or more. Weather data are summarized for Astoria in Seaman (1977). The region experiences cloudy weather an average of 242 days a year, and fog an average of 43 days a year. Winds within the estuary vary somewhat from the regional winds due to masses of heavier air moving down the Columbia River Gorge from east of the Cascades. Wind data for Astoria, presented by Seaman (1977), indicates the winds are from the east and southeast during the fall and winter, and from the northwest in late spring and early summer.

4.3.2 River Flow (2)

River flow into the estuary ranges from a low mean monthly flow of 132,000 cfs in September to a high mean monthly flow of about 495,000 cfs for June (Seaman 1977). The flow is highly regulated by the upstream main stem dams reducing the volume of spring freshets and floods. Characteristics of the riverine ecosystem were presented in Section 4.2. The physical and chemical characteristics of the river affect the characteristics of the estuary water column, substrate, and biological community.

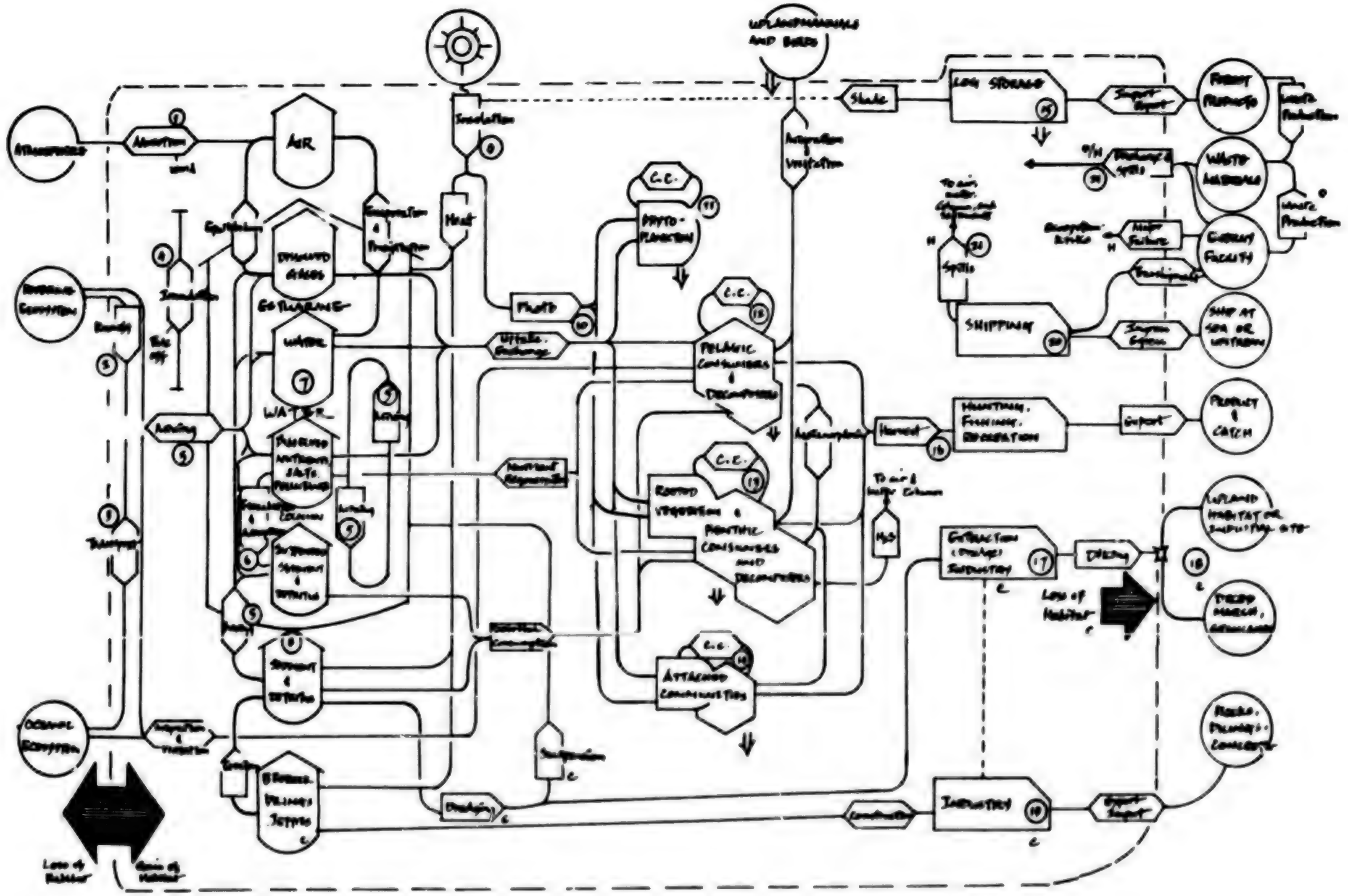

Figure 4.5. Estuarine ecosystem model.

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4.3.3 Tides

This section discusses ocean exchanges (3), tidal inundation (4), and mixing (5). The tidal exchange at the mouth of the estuary ranges from about 0.4 to 1.45 million cfs depending on the range of the tide, and averages about 0.64 million cfs (Seaman 1977). On the average, the in and out tidal flow significantly exceeds the freshwater inflow, being more than twice as strong as the river flow. However, the river flow is subject to wider variations and may almost overwhelm the tidal influence during the spring freshet.

Tidal inundation occurs twice every 24.84 hours and is determined by the height of both the higher and the lower high tide. Mean diurnal tide ranges refer to the average height from mean higher high to mean lower low water. Within the estuary, mean diurnal ranges vary from about 7.5 feet to about 8.5 feet depending on location. Tidal inudations influence the water levels along the entire lower Columbia River with a mean diurnal range decreasing upstream to about 2.4 feet at Portland. Water heights (and hence inundation) are also influenced by river flow, which is regulated for the lower Columbia River by the main stem dams. The extent of this influence on water height is greatest where the river is small in cross-sectional area, and decreases considerably within the estuary, where the cross-sectional area is great. Changes in atmospheric pressure also influence the amount of water that can be held within the estuary, with greater water levels obtained during periods of low atmospheric pressure.

The combinations of tide, runoff, and atmospheric pressure affect the amount of freshwater and oceanic water present in the estuary. The mixture of the two determines the water characteristics at a given location. Seasonal variation in the oceanic water also results from coastal upwelling, which brings nutrient rich water closer to the surface. This water is also naturally low in temperature and dissolved oxygen, and high in salinity and density.

Figure 4.6 presents the average salinity concentrations at different locations above the stream mouth during high and low flow for the Columbia River Estuary at high tide.

Circulation within the estuary is controlled by many parameters, including not only tide, runoff, and atmospheric pressure, but also winds, bathymetry, and Coriolis effect. Because of the wide range in variables, and the impossibility to control these variables in field studies, attempts are often made to mathematically model circulation within the lower river and the estuary. Because of complications in programming and modeling, these efforts are often limited to one dimensional approaches, with two dimensional ones being largely the state-of-the-art. The CREDDP has several tasks oriented toward simulation of the circulation and application of these techniques to problems of salt intrusion and sedimentation. Preliminary analysis of field data obtained for CREDDP indicates that water heights (as measured by tide gauge) and currents (as measured by current meters) are strongly correlated with the release of water at Bonneville Dam, as well as with the tides (Moulton pers. comm.).

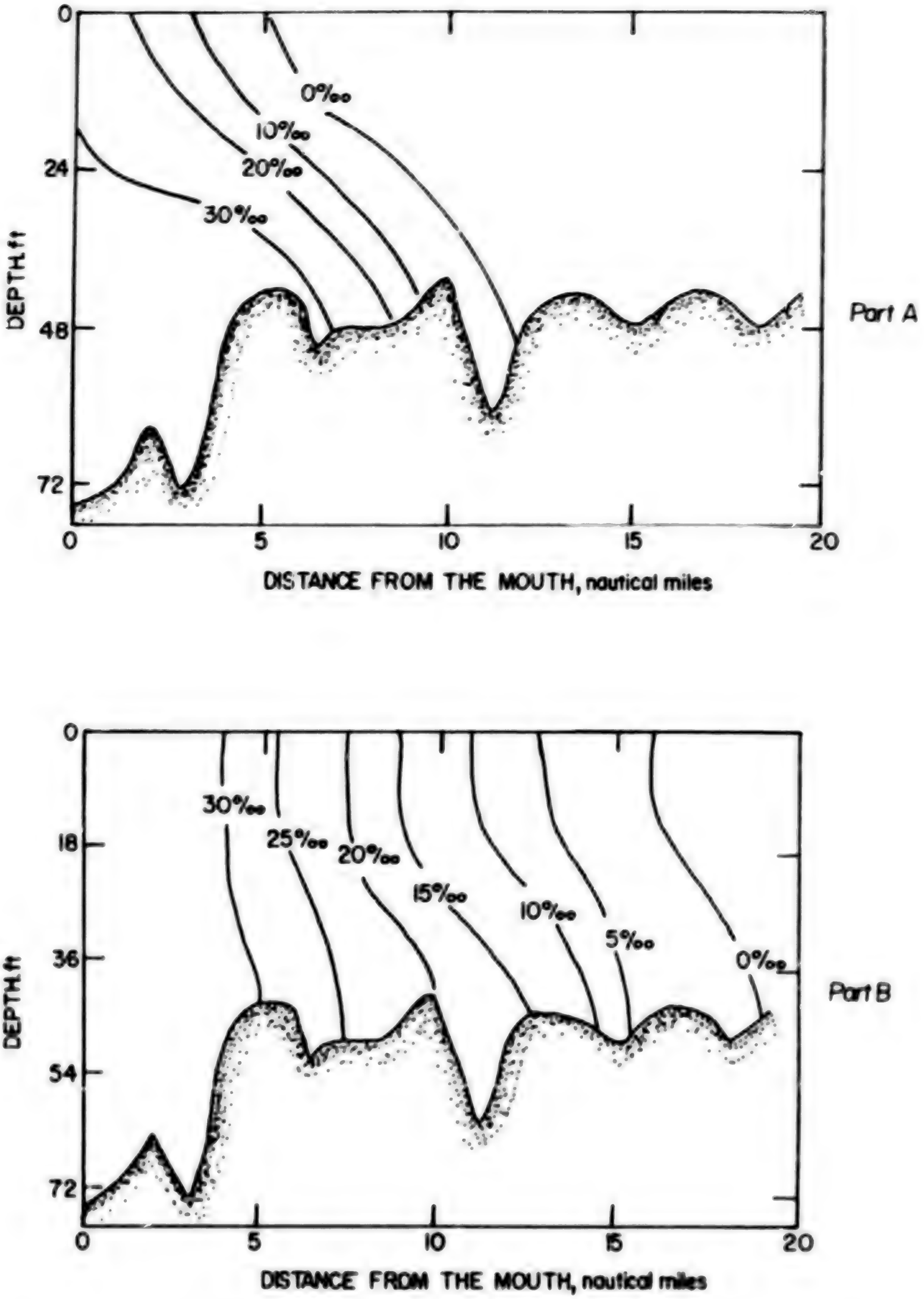

Figure 4.6. Average salinity (ppt: 0/00) at different locations above the mouth of the Columbia River during high flow in the spring and summer (Part A), and low flow in the fall and winter (Part B) at high tide (Neal 1972).

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The methods of mathematical modeling are sufficiently complex, thus, physical modeling, with sufficient data for verification, may be better suited to assessing circulation and distribution of conservative properties (those properties not influenced by biological action or change/decay overtime). Physical model studies have been performed by the U.S. Army Corps of Engineers using a 1.1 acre model of the estuary and lower river, to river mile 52 (Herrmann 1968).

4.3.4 Water Column (6)

The water quality of the Columbia River Estuary was characterized by Envirosphere (1980) for CREDDP, based on an extensive literature review. Park et al. (1972) plotted the monthly distribution of chemical parameters relative to salinity within the estuary for 1966 and 1967 (Figure 4.7). In the figure, lines sloping down to the right indicate water parameters that were supplied primarily from the river runoff, and lines sloping up to the right indicate parameters supplied primarily from the ocean.

The source of nitrate changes with the season; nitrate is supplied to the estuary from the river in the winter, but is depleted in the river in summer months, and supplied to the estuary from the oceanic water. Phosphate showed similar patterns, though it was not completely depleted in the summer in the river water. Phosphate levels from the oceanic water were greater than the highest levels from the river. The lowest levels of dissolved oxygen were associated with oceanic water in the summer and fall and are associated with upwelling along the coast. (The upwelled water is also a source of high nutrients to the estuary.)

Envirosphere (1980) summarized their findings from the review of water quality literature and from sampling after the Mt. St. Helens eruption and concluded: "The results of the water quality literature review generally indicate that the apparent water quality of the estuary is satisfactory to support a diverse aquatic biota and most designated uses." They did note that fecal coliform bacteria concentrations near the upstream study boundary (river mile 35-46) regularly exceeded standards set by both Oregon and Washington, which are 10,000 colonies/100 milliliters.

4.3.5 Sediments (7 & 8)

Reviews of sediment and sediment transport studies are presented by Seaman (1977) and Creager et al. (1980). The latter is an annual CREDDP report by the sedimentation work unit task force. Their studies have included sediment distribution, subbottom profiling, bedform shape analysis, fluorescent tracer studies, sediment mineralogy, and suspended load transport. Analysis is not yet complete, and conclusions are preliminary. The description of the sediments and sedimentation processes given in Seaman (1977) and briefly summarized below is appropriate to this model.

Estuarine sediments provide food, shelter, and substrate for a diverse plant and animal life. Bacteria in the sediment decompose organic wastes

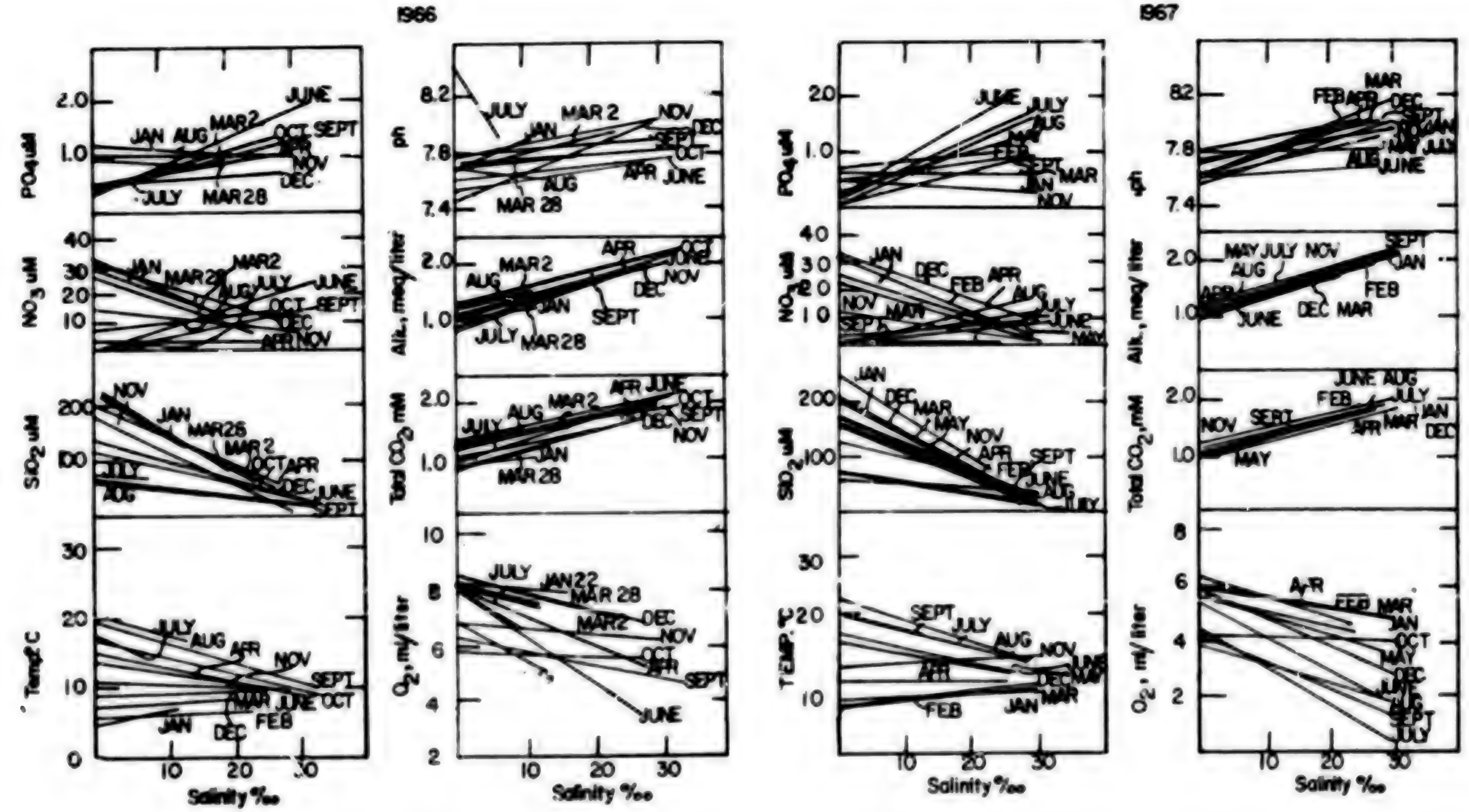

Figure 4.7. Temperature and chemical parameters as a function of salinity in the Columbia River Estuary for the combined years 1966-1967 (Park, Osterberg and Forster 1972).

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and in the process recycle nutrients back into the estuarine system. Dredging and filling directly impact the channels and fill areas and also impact the water column through resuspension of fine materials and possible release of toxins from the sediments.

Most sediments in the Columbia River are inorganic sands, silts, and clays, which are introduced into the estuary from the river and the ocean and, to a lesser degree, tributaries to the estuary. Organic particulates (detritus) behave like fine inorganic materials and settle out in areas of reduced circulation, such as tidal flats, increasing the biological productivity of these areas. They may also concentrate in the mixing zone. Sediments and detritus are suspended and redistributed in the estuary in response to tidal, wave, and river forces, all of which vary significantly on a daily, weekly, monthy, seasonal, and/or annual basis and also vary with location within the estuary. Movement is greatest at times of maximum turbulence, related to river flow, tide, or wave activity.

Seaman (1977) noted that information is lacking to construct a detailed map of the Columbia River Estuary sediment distribution. Information gathered by the University of Washington for CREDDP indicates that there is considerable natural variability in sediment size, dependent on river flow and tides. Seaman (1977) presents a figure showing the location of channels, slopes, and flats within the estuary, and discusses the generalized sediment types found in the marine, transition, and river zones. General observations from Seaman (1977) follow.

> Channels contain the coarsest sediments. River channel sediments are the coarsest; marine channel sediments, intermediate; and the transition channel sediments, the finest. The sediments are moderately well sorted and tend to be skewed toward the coarse material.
>
> Flats contain the finest sediments and those that are most poorly sorted (variable in size). Sediments on flats also tend to be skewed toward fine particles. Of the three longitudinal divisions, sediments are finer in the river and marine divisions than in the transition division, where extensive midestuary sand flats occur (e.g., Desdemona Sands).
>
> Slope sediments are relatively less variable in textural characteristics throughout the estuary and are slightly more uniform in size near the mouth. The particle size, sorting, and skewness on the slopes are between the values observed for the channels and flats.

Seaman (1977) defined the marine zone as occurring from the mouth to river mile 7, and the transition zone as occupying river mile 7 to 23, with the riverine zone continuing upstream of mile 23.

The first 12 months of data collection by Creager et al. (1980) were discussed by Envirosphere (1980) in summary form:

> Sediment grain size on the open estuary flats generally decreases downstream from Harrington Point (from medium to fine sand) and southward from Grays Bay to Cathlamet Bay (from medium sand to silt). Sediment grain size in the deepest portions of the main river channel also decreases downstream from Harrington Point to Desdemona Sands (from coarse sand to find sand) and then increases to the entrance (to medium then to coarse sand).
>
> Bathymetric profiles reveal that the surfaces of flats, channel bottoms, and channel wall ledges seem to exhibit preferred depths (9-12, 24-26, and 34-35 feet, respectively). It is not known whether these might be related to prior lower stands of sea level, resistant subsurface strata, or some, as yet, unidentified phenomenon.
>
> The nature of bedforms suggests net downstream transport of sediment as bed load above Tongue Point. Near the river mouth, as expected, bedforms suggest reversing directions of bottom sediment transport in response to tidal flow. However, as shown in the dyed sediment tracer experiment, there is a net transport of bottom sediment seaward along the south wall of the main channel, off Jetty A, during late summer. The lower estuary, from the tip of Desdemona Sands to Tongue Point, is a transition zone for bed load sediment transport.
>
> Distinctive mineral grains from a source in Tillamook Head, Oregon, are found in the river as far north as Desdemona Sands and may be usable as an indicator of upstream transport from offshore.
>
> Ash of the recent Mt. St. Helens eruptions is quite similar in mineral composition to the Columbia River sediments, though the relative abundances of constituents differ.
>
> Suspended load transport studies in Baker Bay indicated that there is a net accumulation of suspended sediment transported through Ilwaco Channel.

The significance to the estuarine ecosystem of the channel wall ledges noted by the University of Washington studies is not known. A major problem in assessing their significances lies in the accuracy of station positioning, which prior to CREDDP was not sufficient to define a sample as being from the slope or a wall ledge.

Shoaling in the estuary has increased because of human activities. Probably the most significant factor has been the effect of main stem dams in reducing the peak runoff, which once carried accumulated sediment out to the Pacific. (Dams also decrease the sediment load of the river.) Increasing of the navigation channel depth to 25 feet in 1885, and to the present 48 feet, increased the salinity penetration, thereby affecting the position and settling characteristics of the mixing zone and increasing sedimentation. Lockett (1967) noted that between 1868 and 1958, a net shoaling of about 77,000,000 cubic yards occurred between upper Sand Island and Tongue Point. This equates to a filling in rate of 15 percent/century for the estuary. Obviously, the estuary is adjusting its configuration to the conditions which result from the human alterations. The midestuary flats have been accreting mostly sand, while shoaling in Youngs Bay, Baker Bay, and by the port of Astoria has been finer material.

Envirosphere (1980) reviewed the available data on sediment chemistry and noted that given the limited data base it was difficult to draw any conclusions concerning estuary sediment chemistry other than that the sediments are probably not a broad pollution source and that they could probably assimilate additional organic loading.

4.3.6 Insolation (9)

Insolation data were discussed in Section 4.2. Total maximum possible solar radiation varies from over 1,000 langleys per day in late June to about 250 langleys per day in late December. Because of cloud and fog cover, the actual solar radiation at Astoria averages out to 70 langleys per day in December to 474 langeleys per day in July. Monthly average solar radiation data were presented in Figure 4.4.

4.3.7 Productivity (10)

Primary productivity was studied under three separate tasks for the CREDDP. These were Emergent Plant Production, Benthic Primary Production, and Water Column Primary Production. These studies are not yet complete, but preliminary findings are summarized by Envirosphere (1980) and are detailed below.

4.3.7.1 Emergent Plant Production. An objective of this CREDDP study was to measure and map the distribution of net primary emergent plant (marsh) production throughout the estuary. The analysis of the above ground vascular plant biomass for April and July 1980, and decomposition rate data for selected plant species indicated that:

> Estimates of annual net above ground plant production values for different sites throughout the estuary ranged from 311 to 1,969 g dry wt/m^2.
>
> The average annual net production of above ground plant material in the marshes west of Tongue Point was 955 g dry wt/m^2 which is greater than the estimated annual net production for marshes east of Tongue Point (733 g dry wt/m^2).
>
> Low marsh stations west of Tongue Point were more productive than upper marsh stations (1,003 vs. 795 g dry w/m^2). Whereas, upper marsh stations east of Tongue Point had a higher production estimate than low marsh stations (850 vs. 729 g dry wt/m^2).

> The estimated annual net carbon production for marshes west of Tongue Point is 430 g C/m^2, and 348 g. C/m^2 east of Tongue Point.
>
> Plant material decomposes more rapidly at upriver locations than downriver locations.

4.3.7.2 Benthic Primary Production. A further study objective was to determine the mechanisms which control the production dynamics of benthic plants in the estuary and to evaluate the effects of chemical, physical, and biological mechanisms on the structure and function of benthic algae. Preliminary results indicate that:

> The highest mean rate of gross primary production (GPP) occurred in Youngs Bay with 108.46 mg C/m^2/hr, followed by Bakers Bay 53.89, Quinns Island 35.44, Grays Bay 32.36, and Clatsop Spit 3.00.
>
> GPP rates declined during June and July especially at the lower intertidal levels. This was attributed to increased sediment loads due to Mt. St. Helens eruption.
>
> GPP rates appear to be closely associated with sediment stability: the more stable the substrate, the higher the GPP.
>
> GPP rates declined as marsh plants developed and shaded the surface, and increased as marsh vegetation declined in August and September.
>
> Chlorophyll a concentrations were highest in the upper centimeter of sediment. Chlorophyll concentrations were highest in the marsh and lowest in the lower intertidal zone.
>
> Organic matter concentration in sediment samples was fairly constant during the study period, both spatially and temporally.
>
> Diatoms were the most abundant flora on the tidal flats, but diatom species composition varied greatly among sites. Blue-green algae were found under the emergent marsh plants, but very few macrophytes were found.

4.3.7.3 Water Column Primary Production. A final objective of the CREDDP study was to determine water column primary production; its importance within the estuary; the rates of primary production, both temporal and spatial; spatial and temporal biomass distribution; and the factors controlling the distribution, abundance, and fate of the water column phytoplankton. Preliminary findings from this study are:

> Primary production appears to be a function of the amount of biomass present, the degree of light penetration, and the availability of inorganic nutrients.

Horizontal distribution appears to be controlled by the most important water source for the area involved. The upper estuary distribution is controlled by the Columbia River; bay areas, by tributaries; and river mouth distribution, by the sea.

Biomass is relatively homogenous vertically except in the mixing zone.

The Mt. St. Helens eruption reduced water column primary production greatly during late May and June of 1980.

Seaman (1977) notes that, "freshwater phytoplankton are most abundant between April and September, with maximum peaks of 17,000 and 26,000 cells/ml in May of 1967 and 1968, respectively. Populations are low to nonexistent in winter. Marine phytoplankton populations reached a maximum of 600 to 1,600 cells/ml in late summer of 1967 and 1968." The most abundant phytoplankton are freshwater diatoms. This is due to the high freshwater flow through this estuary especially during the spring and summer months of high light availability. Other Pacific Northwest estuaries have their peak freshwater throughput in the winter, with the marine waters dominating the summer period when productivity is highest.

The combined primary production of the estuarine wetlands, the benthos, and the water column supports the food chain within the estuary. The marsh plants in the wetlands export detritus, forming the base of the food chain, whereas the phytoplankton is directly grazed upon. It is not yet determined whether water column phytoplankton or detritus is the principal source of energy for animal protein production (Envirosphere 1980). Each source is important to a variety of species of concern at higher trophic levels.

4.3.8 Community Composition

The community compositions presented in the CPCR, Vol. 3 for the various habitats in the subtidal and intertidal estuarine zones are applicable to the Columbia River Estuary. The column entitled "range" lists the different watershed units in which individual species occur; the Columbia River Estuary is identified by the number 3. The community composition printouts within Volume 3 of the CPCR failed to note the occurrence of the following freshwater diatoms which, due to the large river flow, are dominant within the Columbia Estuary (a significant difference compared to other Pacific Northwest estuaries): *Melosira* spp., *Fragilaria crotonensis*, *Asterionella formosa*, *Stephanodiscus astrea*, and *Syndra ulna*. These diatoms are characteristic of eutrophic lakes (Seaman 1977).

The following discussion on community structure was developed by the CREDDP and presented in the annual summary report by Envirosphere (1980).

4.3.8.1 Invertebrates. The invertebrate community of the Columbia River Estuary is a diverse assemblage of organisms occupying both the water column and the sediments. Some forms are strictly planktonic, occupying the water column for their entire life cycle. Others are epibenthic, occupying the water column at times for feeding or migrations and spending the rest of the time on or in the sediments. Those that are considered strictly benthic (bottom) dwellers often have planktonic larval stages. The surveys undertaken during the first year of CREDDP sampled each of these habitats with a variety of gear and techniques, and provided insight into the structure of the invertebrate community of the estuary.

Plankton invertebrates. The invertebrate plankton community of the estuary is dominated by various crustaceans, including copepods, mysids, and cladocerans. The key species in terms of abundance and/or biomass appear to be: the copepods, *Eurytemora affinis*, *Cyclops bicuspidatus*, and *Arcartia clausi*; the mysids, *Archaeomysis grebnitzkii* and *Neomysis mercedis*; and the cladoceran, *Daphnia spp*.

The community composition varies with the salinity pattern in the estuary. The division of the estuary into three salinity zones is given in the introduction to Section 4.3 above. In the marine zone, *Acartia clausi* and *Archaeomysis grebnitzkii* dominate the plankton. In the mixing zone, *Eurytemora affinis* and *Neomysis mercedis* dominate. In freshwater, *Daphnia spp*. and *Cyclops bicuspidatus* predominate. The distribution of these groups varies geographically with the season as discussed above.

Epibenthic invertebrates. The epibenthic invertebrates include those organisms found near or on the bottom. They include plankton organisms described above and those invertebrates dwelling at the sediment surface. The key bottom dwelling types and species in terms of numbers and biomass appear to be: the copepod, harpacticoid; the ostracod, amphipods (small shrimp-like organisms sometimes called freshwater shrimp or scud), *Corophium salmonis*; the decapods, *Crangon franciscorum* (a small shrimp) and *Cancer magister* -- Dungeness crab (juveniles).

Corophium salmonis and *Crangon franciscorum* were the most abundant species in terms of biomass. The copepods and ostracods, although numerous, were of secondary importance in terms of biomass.

Like the plankton, the distribution of the epibenthic forms depends on the freshwater flow and salinity distribution in the estuary. *Crangon franciscorum* and *Cancer magister* are found predominantly in the marine portion of the estuary. *Corophium salmonis* predominates in the freshwater and mixing zones.

Benthic invertebrates. The benthic invertebrate community includes crustaceans, barnacles, polychaete worms, oligochaete worms, clams, snails, shrimps, crabs, and insect larvae. The most important taxa in terms of numbers and biomass are: the crustacean, *Corophium salmonis*; the polychaetes (marine worms); the oligochaetes (freshwater worms); the bivalves (clams), *Corbicula manilensis*, *Macoma balthica*, and *Mya arenaria*; and the chironomids (insect larvae).

The community composition varies considerably with the salinity pattern within the estuary. In freshwater and mixing zones, oligochaetes, *Corophium salmonis*, *Corbicula manilensis*, and chironomids predominate. Polychaete worms and the clams *Macoma balthica* and *Mya arenaria* dominate the benthos in the marine zone.

4.3.8.2 Fish. The fish community of the Columbia River Estuary is a diverse assemblage of marine, anadromous, estuarine, and freshwater fishes which use the estuary for spawning, nursery, feeding, and migratory purposes. The major species in the estuary based on the CREDDP surveys and previous studies are listed in Table 4-9.

Marine fish. Of the marine fishes, the starry flounder and Pacific staghorn sculpin use the estuary most extensively. They are year-round residents and can be found from the mouth of the river to the freshwater areas of the upper estuary; however, they predominate in the marine and mixing zones.

Other marine fishes use the estuary for spawning and nursery areas. Most marine fishes are fall and winter spawners, spawning offshore or in the estuary from October through February. Larval forms are present from fall through spring. Juveniles of sole, herring, and anchovies can be found year-round in the estuary. Smelt young are found in the lower estuary in the spring and early summer. Pacific herring and northern

Table 4-9. Major fish species in the Columbia River Estuary.

Marine	Anadromous	Estuarine and freshwater
Starry flounder	Eulachon smelt	White sturgeon
English sole	Pacific lamprey	Yellow perch
Pacific staghorn sculpin	Chinook salmon	Longfin smelt
Pacific herring	Coho salmon	Prickly sculpin
Northern anchovy	Chum salmon	Northern squawfish
Surf smelt	Steelhead trout	Largemouth bass
Night smelt	Cutthroat trout	Freshwater catfishes
Pacific tomcod	American shad	Peamouth and carp
Green sturgeon		

Source: Envirosphere 1980.

anchovy are known to spawn in the lower estuary. Their young, along with the smelt and English sole larvae, make up the bulk of the ichthyoplankton in the marine zone of the estuary.

Anadromous fish. The anadromous fishes are the most economically important fish using the estuary. They include the Columbia River salmon and steelhead stocks, along with Eulachon smelt, American shad, cutthroat, and Pacific lamprey. All except the Pacific lamprey support important commercial or sport fisheries in the ocean, river, or estuary. They all migrate from the ocean as adults to spawn upriver and in tributaries. Young migrate downstream and through the estuary to the ocean. They spend varying amounts of time within the estuary, depending on the species.

Chinook salmon and Eulachon smelt are found within the estuary more often than other anadromous fishes. Chinook salmon fry are abundant from May through September with peak abundance in July and August, when they made up 50 percent or more of purse seine collections in 1980. Eulachon smelt larvae are predominant in the ichthyoplankton from February through May, and fry (juveniles) are abundant during the same period.

The adult runs and downstream migrant young of these fishes pass through the estuary at specific times of the year. Table 4-10 presents a summary of these migrations.

Estuarine and freshwater fish. The white sturgeon, longfin smelt, and prickly sculpin are important permanent residents of the estuary. The white sturgeon is usually found in the deeper parts of the estuary. They migrate upriver in late winter and spring to spawn. The longfin smelt is abundant during most of the year; adults spawn in the estuary during the winter, and the larvae dominate the winter ichthyoplankton. Juveniles are abundant during the summer. Prickly sculpin is an estuarine resident which spawns in the spring, and their larvae dominate the spring ichthyoplankton.

Yellow perch, largemouth bass, freshwater catfish, peamouth, northern squawfish, and carp are also common residents of the upper freshwater portion of the estuary.

Various work units with CREDDP evaluated predator-prey relationships from their own research, and from the literature, in order to characterize the basic food chain and flow of energy within the estuary. Figure 4.8 presents the generalized food chain as developed by the CREDDP program.

Species of concern to the USFWS are discussed in Chapter 5 and include Chinook and coho salmon, steelhead trout, shad, sturgeon, Dungeness crab, Corophium spp. (an important food source for higher trophic levels), waterfowl and shorebirds, great blue heron, western/glaucous winged gulls, bald eagle, and Columbian white-tailed deer. The model (Fig. 4.8) portrays migration and visitation of upland mammals and birds as well as animals (fish or mammals) from the river and ocean boundaries. The migration habits of the species of concern are also discussed in Chapter 5.

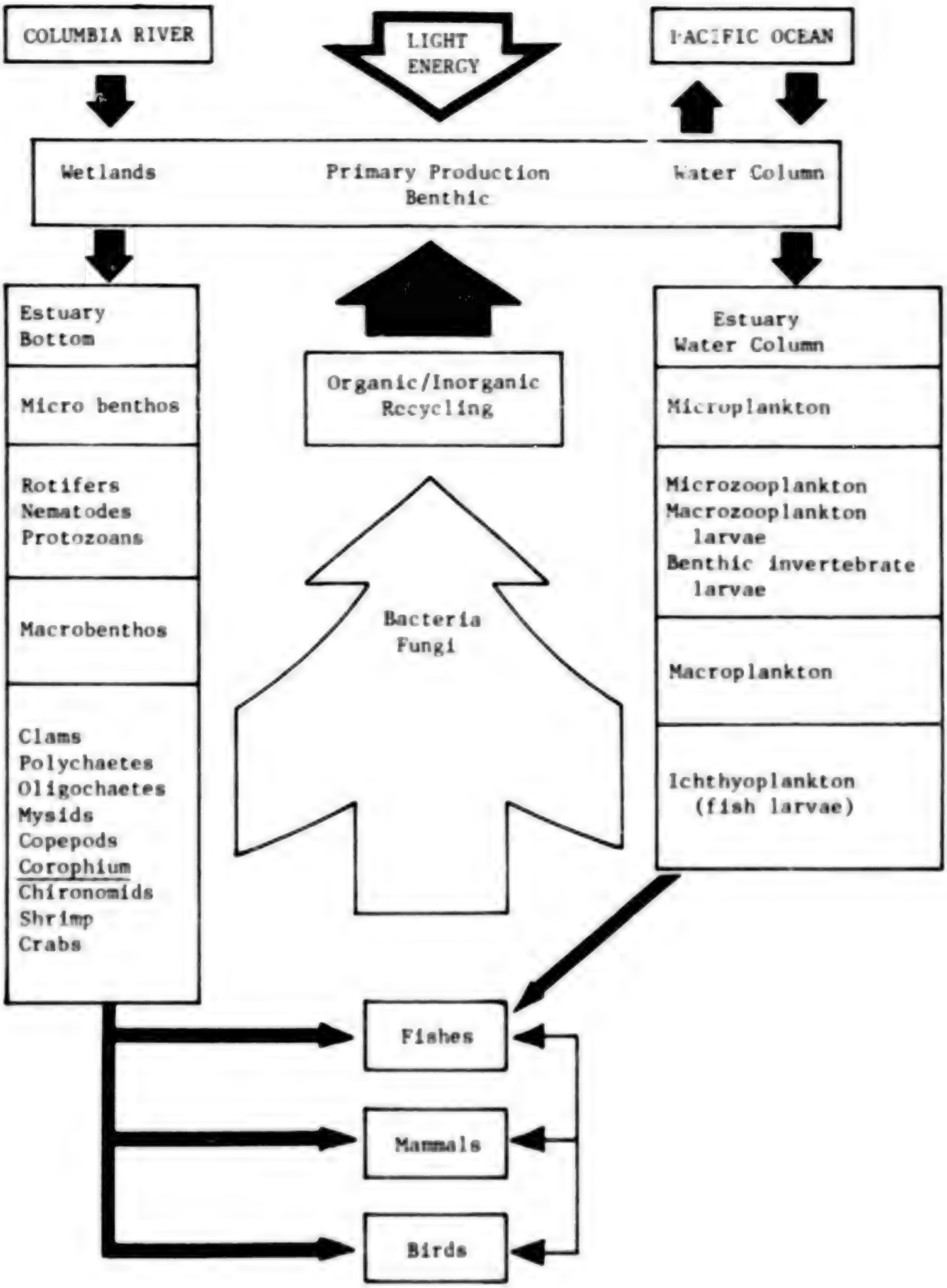

Figure 4.8. Simplified food chain for the Columbia River Estuary (Envirosphere 1981).

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Table 4-10. Monthly appearance of juvenile and adult anadromous fish species in the Columbia River Estuary.

Species	Months present in estuaries	
	Adults	Juveniles
Chinook salmon		
spring-summer run	late March to June	April - September
fall run	late July to early September	
Coho salmon	August through October	April - June
Chum salmon	November and December	April - June
Steelhead trout		
summer run	April - October	April - June
winter run	November - April	
Cutthroat trout	December - February	April - June
American shad	May - July	September - November

Source: Envirosphere 1980.

4.3.9 Log Storage (15)

Log storage occurs in the Deep River (tributary to Grays Bay) and in the nearshore channels of Cathlamet Bay (Sutherland 1979). Impacts of log storage are localized, and include concentration of organic matter (bark) in the sediment, shading, leaching of potentially harmful natural wood oils, and physical impacts on benthic organisms. Log storage also creates sheltered habitats and shade which may be desirable to some species.

4.3.10 Hunting, Fishing, and Recreation (16)

The primary impact of these human activities is the harvest of important species from the community. This impact on the estuarine community occurs from the combined harvest from within and outside the estuary. Salmon are caught at sea and also upstream beyond the estuary. Sturgeon may be taken in the estuary or in the lower river. Waterfowl are subject to hunting pressures at other locations along their extensive migration routes. These species require comprehensive management of the resource, based on accurate assessments of the available stock. The Pacific Fisheries Management Council (1979) is developing a Fishery Management Plan for commercial and recreational salmon fisheries off the coast of Washington, Oregon, and California.

4.3.11 Dredging (17)

The estuary has been shoaling at a rate of about 15 percent per year, thereby requiring considerable maintenance dredging. Table 4-11 presents a summary of maintenance dredging requirements for the study area based on the workload from fiscal years 1968 through 1972. This table does not reflect the additional sediment loading from the Mt. St. Helens eruption which blocked the navigation channel at the confluence of the Cowlitz River (river mile 66).

Dredging of the navigational channel does not always remove sediment from the estuary. Rather, it relocates it along the shore, or on islands. Ocean disposal of dredged material has also occurred. Dredge disposal sites in the estuary are presented by Seaman (1977) and in the appended atlas. The sediment is mostly clay and silt and precipitates out in the transition zone under moderate to low river flows.

4.3.12 Industry (18)

Industrial development is primarily confined to the Astoria area on the Oregon side. Wetlands have been filled along the Astoria waterfront, at the entrance to Skipanon waterway, and at the south end of Youngs Bay. Pier pilings along the Astoria waterfront and South of Tongue Point have created new habitats within the estuary. Pier habitats were modeled in the CPCR, Volume 3.

Industrial siting may also create (or increase) the need for additional dredging; hence, there is a connection illustrated between dredging and industry. The recreation industry can also create dredging requirements and pier construction. Ilwaco, Washington supports a large sport fishing industry and requires moorage and dredged channels. Chinook, Washington also has a dredged channel to support its small boat operations. A proposed coal terminal for Tongue Point may also lead to a deepening of the navigation channel and the Columbia River entrance bar to handle larger vessels.

4.3.13 Shipping (19)

Shipping in the Columbia River includes large marine vessels, fishing and recreational boating, and tug and barge (or log raft) traffic between ports in the Columbia River system. The Corps of Engineers listed ship arrivals, by cargo and draft characteristics for 1971 (U.S. Army Corps of Engineers 1974). Arrivals totaled 1,520 (see Table 4-12). Additional vessel movements between ports within the Columbia River also occurs. These data do not include the smaller vessel movements within the estuary (fishing, boats, tugs, etc.). Seaman (1977) noted that there were 4,080 crossings of the entrance bar by deep draft vessels in 1973.

Table 4-11. The method, frequency (years), and volume (cubic yards) of dredge materials taken from the Columbia River Estuary from 1968 to 1977.

Location	River miles	Dredging method		Frequency[a]	Volume[b] (yds^3/yr)
		Hopper	Pipeline		
Astoria Area	3-21	X		5	
Miller Sands	22-25	X	X	5	800,000
Pillar Rock	25-28	X	X	5	185,000
Brookfield	28-30	X		5	170,000
Welch Island	30-33	X		As Needed	100,000
Skamokawa	33-37	X	X	1	120,000
Puget Island	37-40.5		X	3	240,000
Wauna-Westport	40.5-45		X	5	490,000
Upper Westport	45-49		X	5	250,000
Eureka	49-53		X	4	180,000
Gull Island	53-56		X	2	50,000
Stella-Fisher	56-59.5		X	4	285,000
Walker Island	59.5-63.5	X	X	3	180,000
Slaughters	63.5-67	X	X	4	160,000
Lower Dobelbower	67-70	X	X	3	180,000
Upper Dobelbower	70-73		X	3	130,000
Kalama	73-77		X	4	280,000
Lower Martin Island	77-80		X	2	70,000
Upper Martin Island	80-84		X	4	410,000
St. Helens	84-87		X	As Needed	60,000
Warrior Rock	87-90		X	2	130,000
Henrici	90-94		X	4	250,000
Willow	94-98		X	4	415,000
Morgan	98-101		X	3	200,000
Vancouver	101-106		X	3	230,000

Source: U.S. Army Corps of Engineers (1974).

[a] Number of years dredged in five year period.

[b] Average annual amount dredged in cubic yards.

Table 4-12. Ship draft by cargo on the Columbia River in 1971.

Cargo	Average draft	Vessels arriving			
		35 FT +[a]	30-34.9	25-29.9	Less Than 25
Alumina	34'-05"	19	17	8	0
Automobiles	21'-06"	0	3	9	27
Cement	19'- 0"	0	0	1	7
Flour	21'-06"	0	0	0	3
General Cargo	22'-02"	2	48	151	578
Grain	20'- 0"	0	3	13	137
Iron Ore	38'- 0"	6	0	0	0
Logs	22'- 0"	0	2	18	62
Lumber	2'- 0"	0	0	1	20
Petroleum	31'-06"	22	206	56	13
Salt	30'-09"	2	6	4	1
Scrap Iron	22'- 0"	1	1	7	16
Area	30'- 0"	0	1	1	0
Wood Chips	22'-01"	0	4	7	37
Total Ships		52	291	276	901
Percent of Directional Movement[b]		3.42	19.15	18.16	59.27

Source: U.S. Army Corps of Engineers (1974).

[a] See Note in Text. A ship with a draft of 35' requires a greater channel depth.

[b] Total Ships Directional Movement - Arriving = 1,520, Departing = 1,731. The excess of Departures is caused by counting procedures where a ship leaves more than one port while on the Columbia River.

OIW (1978a) in evaluating risks of oil spills on the Columbia River presented data on port calls by self-propelled and nonself-propelled vessels in the Columbia River and lower Willamette River and for the Ports of Portland and Vancouver (Table 4-13), including tug and towboat traffic, and vessel traffic from these ports to ports up the Columbia, beyond several dams (via locks). Petroleum commerce on the lower Columbia has remained fairly steady from 1973 to 1977 at about 6,000,000 tons per year. Large numbers of internal shipments indicated extensive amounts of petroleum were transferred from tanks and storage facilities to small ships and barges (OIW 1978a).

The vessel traffic is increasing, and subsequent energy developments in the study area will lead to further increases. With these increases arise increased pressure for deepening the channels to accommodate larger vessels. Increased shipping also increases the risks of accidents which could spill oil or other toxic materials.

4.3.14 Discharges and Spills (20)

Both small, chronic spills and large, infrequent spills can severely impact the river and estuary. The swift flow of the Columbia River can rapidly carry a spill downstream, making containment and recovery operations difficult. OIW (1978a) evaluated oil spill clean-up capabilities within the Columbia River and Estuary for the U.S. Coast Guard. They also compiled data on oil spills in the Columbia, compared it to data from five other rivers, and performed a spill frequency analysis for vessels, bulk storage and transfer operations, railroads and highway carriers, and pipelines.

During the OIW study, 26,000 gallons of heavy fuel oil (Bunker C) spilled into the river over a 13 hour period from the TOYOTA MARU on 28 June 1978. The spill occurred at river mile 101.5. Forty-five minutes after the spill was reported, there were oil patches 1.5 miles downstream. Five and a half hours later, there was heavy oil 2 miles downstream and, also, 2 miles up the Willamette River. Within 10 hours, the oil covered the river 17.5 miles downstream and some oil had reached 26.5 miles. After 41 hours the oil was heavy at 40.5 miles downstream from the spill (on river mile 61, west of Longview).

Data for oil spills greater than 100 gallons over the period, 1973 to 1977 are presented in Table 4-14; Table 4-15 provides vessel trips for the same time frame. OIW (1978a) evaluated spills of over 100 gallons vs. trips for tankers, tank barges, and other vessels in the Columbia River System and obtained spill rates of .000833, .000355, and .000082 spills per trip, respectively. Using these numbers, it is possible to estimate risk increases from increases in shipping.

Sutherland (1979) prepared an oil spill protection plan for the lower Columbia River and estuary in which he identified where best to position equipment to protect the resources of the system. A weakness to the plan is that all the boats and equipment called for are not prepositioned at the sites for rapid use.

Table 4-13. Vessel calls in the Columbia River and lower Willamette River and for the Ports of Portland and Vancouver.

Year	Self-propelled			Nonself-propelled	
	Passenger & dry cargo	Tanker	Towboat or tugboat	Dry cargo	Tanker
Columbia and Lower Willamette Rivers					
1973:	4,350	716	51,981	19,480	4,084
1974:	3,447	600	46,881	20,188	3,529
1975:	12,194	676	46,748	16,552	3,894
1976:	12,022	647	43,884	15,358	4,600
1977:	12,095	617	44,424	16,883	4,725
Ports of Portland/Vancouver					
1973:	2,637	692	25,532	13,754	3,828
1974:	2,226	536	23,295	15,218	3,351
1975:	2,026	622	25,092	11,228	3,742
1976:	2,080	587	23,944	10,210	4,411
1977:	2,248	572	25,061	11,197	4,592

Source: Waterborne Commerce of the United States (in OIW 1978a).

Table 4-14. Hazardous chemical spills greater than 100 gallons in different locations in 1973 to 1977.

Vessel	Columbia River	Corpus Christi	Hudson River	Newport News	Mobile	Pascagoula
Tanker	6	5	6	8	3	3
Tankbarge	5	14	13	5	12	10
Passenger/Dry Cargo	16	0	0	0	3	0
Tug/Towboat	2	1	1	1	2	1

Source: Pollution Incident Reporting System, USCG (in OIW 1978a).

Table 4-15. Types of vessels and vessel arrivals in different port areas in 1973 to 1977.

Vessel	Columbia & Lower Willamette	Corpus Christi Canal System	Hudson River System	Newport News	Mobile Harbor	Pascagoula
Tanker	3,255	7,030	10,520	5,330	1,635	2,000
Tankbarge	20,000	31,995	46,840	3,475	22,890	24,520
Passenger/ Dry Cargo	44,110	20,145	65,960	43,825	11,410	17,850
Tug/ Towboat	233,920	20,235	236,265	34,525	35,935	21,010

Source: Pollution Incident Reporting System, USCG (in OIW 1978a).

Other hazards associated with marine vessel traffic include fire or explosion, which could result from a collision, lightning, or human error. If LNG or LPG vessels are involved, the explosion hazard may increase. LNG/LPG hazards were evaluated by OIW (1978a).

4.4 CHANNEL MODEL

The ecosystem model for the estuarine channel habitat is presented in Figure 4.9. The general estuarine model (Section 4.3) also pertains to the channel; however, this section treats certain features of the channel habitat not fully developed in the preceding discussion.

Channels within the Columbia River and its estuary are both natural and man-made. Dredged depths of the main navigational channel are variable, but are in excess of 37 feet relative to the estuary datum of mean lower low water (west of Harrington Point) or the river datum (east of Harrington Point). Smaller dredged channels exist, serving the sport fishing communities of Ilwaco and Chinook, Washington. Natural channels also occur throughout the estuary, and may carry significant amounts of the river flow. Some channels are isolated from the main river flow, and the circulation is mostly tide driven. CREDDP studies carried out by the University of Washington indicated that there are several preferred depths to these channels and other bathymetric features, which may be controlled by morphologic features.

Energy developments bordering the river or estuary may require dredging of addititonal channels or widening and deepening of existing ones to permit access. Channel construction impacts are discussed for the preexisting habitat.

Atmospheric features (climate, insolation, etc.) are regional and no changes occur on a small scale that could distinguish channels from nonchannels. The discussion from Sections 4.2 and 4.3 pertain.

Channels receive water both from river flow and from tidal flow from adjacent estuarine habitats. Included within this runoff are suspended and dissolved materials from upstream, from tributaries, and from direct runoff from uplands adjacent to the estuary. Upstream waste loading, including both nonpoint sources (e.g., septic tanks, agriculture, road runoff) and point sources (e.g., pulp mill discharges, refinery effluents, and treated sewage discharges) contribute to the suspended and dissolved material load of the estuary. Detritus is exchanged between the marshes and channels. Detritus flow is included within the runoff and tidal transport processes from adjacent estuarine habitats within the model.

The blending of riverine and oceanic tidal waters in channels produces salinity and stratification characteristics that vary with season, tide stage, tide range, and other factors (see Section 4.3). The characteristics of channel flow and mixing of ocean and river water are important to sedimentation processes and biological processes. The mixing zone

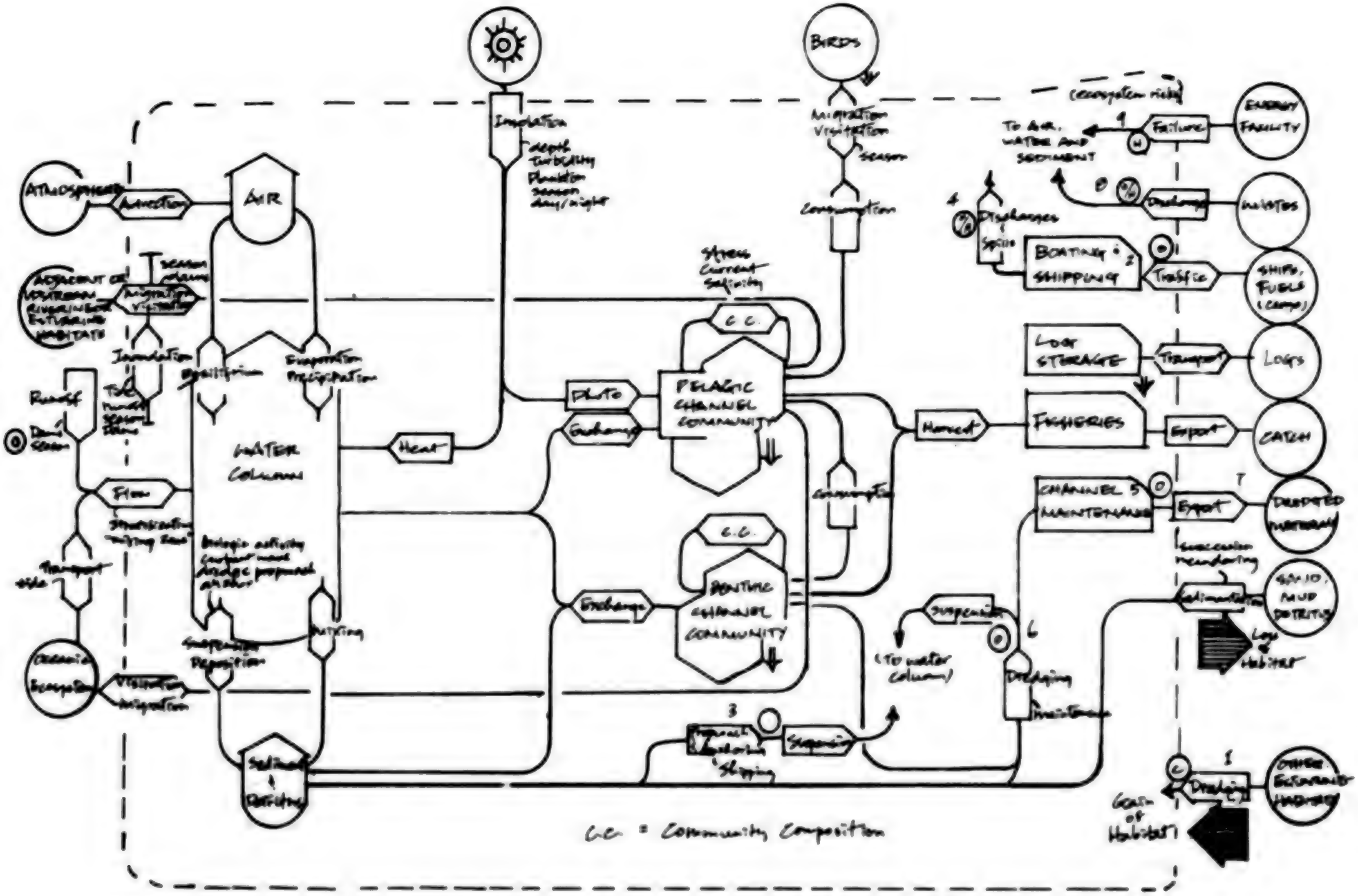

Figure 4.9. Channel ecosystem model.

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is identified as having salinities of 0.05 to 10 ppt. The deposition of fine materials occurs within this zone. During high river flows, fine materials are resuspended and transported within active channels, but in the inactive channels, which do not presently carry much of the river flow, the fine materials remain. Sediments in the active channels are coarser than those on the adjacent slopes or flats, while finer sediment characterize the inactive channels (Envirosphere 1980).

Biological community composition varies seasonally with changes in the salinity regime and the location of the mixing zone. This influences the timing of anadromous fish migration, as well as the occurrence of marine mammals and waterfowl. Adult anadromous fish migrate via these channels, while juveniles generally keep to shallow flats during their seaward migration. Commercial fishing for anadromous fish is concentrated in channels throughout the river and estuary. The community composition for the estuarine channel habitat is presented in the CPCR, Vol. 3, pp. 2.1.1A-2 to 2.1.1A-6, with the number 3 in the range column indicating that the species are found in the Columbia Estuary. Species of concern identified by the USFWS are described in detail in Section 5 of this report. Section 5.14 describes other species of concern identified by other agencies, including the list of key taxa from the CREDDP. The CREDDP list will probably increase as data are further developed (Envirosphere 1980). It is anticipated that the locations, key habitats, and limiting factors, and their interactions and importance to the estuary ecosystems, will be discussed in a future CREDDP Final Report (Envirosphere 1980).

The sequence of construction impacts, operation impacts, and hazards associated with energy facilities will be used to guide the discussion of the channel model. Numbers in parenthesis will refer to numbered locations in the model.

4.4.1 Construction Related Impacts

Dredging to create a channel (1) impacts estuarine and riverine ecosystems (see Section 3.4.1), mainly the habitat from which the channel was dredged. In terms of distribution of ecosystem types, dredging to create a channel represents a gain of channel ecosystem.

The present administration and Congress are evaluating bills to reverse the historical practice of government subsidy of major dredging projects. Many inland ports, including those on the Columbia River, have argued that if public subsidy of dredging ends, then costs should be paid by inland and coastal ports. Coastal ports principally oppose the concept of federally imposed port user fees to subsidize inland ports (Seattle, Post-Intelligencer, July 27, 1981, pg. B12). Because of the competitive nature of port operations the ability of inland ports to compete economically with coastal ports hinges on how this issue is resolved.

4.4.2 Operation Related Impacts

A dredged channel permits navigation of vessels (2). Propwash from these vessels can result in a resuspension of bottom sediments (3).

Vessels will also resuspend sediments when raising, and lowering their anchor and when swinging at anchor (3). Vessels also contribute some pollution through discharges and littering (4). Navigation channels require periodic maintenance dredging (5,6) which resuspends sediments, disturbs benthic habitats, removes the benthic community, and disrupts the estuarine food chain. Dredged materials may be removed from channels (7) to other parts of the estuary, to upland or wetland fill sites, or to the continental shelf beyond the mouth of the river. The depth of the dredged (or natural) channel influences the inflow of marine water and its mixing with the fresher surface waters. During the summer, thermal stratification results.

Energy facilities bordering the estuary and river may discharge wastes (e.g., heat, treated sewage, chemicals) which then mix with the receiving water (and its existing waste load) and pass through the channels downstream. From the channel, these materials can enter other habitats, and thus, are available for uptake by the pelagic and benthic estuarine communities and, through the food chain, by waterfowl, seals, and humans.

4.4.3 Hazards Related Impacts

The channel habitat is not likely to be physically altered by any energy related hazard. It may be chemically altered through the discharge of waste materials or the spilling of fuel or crude oils (4,8). Such alteration may be chronic or temporary. The materials may partly settle out into the sediments where routine maintenance dredging can resuspend them. Contaminated sediments require special disposal practices.

Physical failure of an energy facility can result in a number of hazards. Hydroelectric dam failure on the Columbia River, could result in currents and inundations that would drastically alter existing estuarine habitats, fill channels, and scour or erode existing habitats. LNG fuel oil fires or explosions can cause mortalities to pelagic organisms. The impacts on the pelagic communities would be short-term, given the dynamics of the river and estuary. The toxic effects of an oil spill or petrochemical product, would be short-term in the water column of the channel, but possibly long-term in the bottom sediments. Channels can be a conduit for rapidly transporting pollutants.

4.5 SANDFLAT AND MUDFLAT HABITATS

Sandflats and mudflats are combined for discussion as habitat boundaries are not distinct, and the biota and estuarine processes are similar. These intertidal and shallow subtidal habitats typically have low bed slopes and are exposed to low current velocities in the estuary. Flats within the estuary may be bounded completely by slopes, such as Desdemona Sands, or may lie between the slopes and the shore. Generalized sediment types in the marine, transition, and riverine zones of the estuary are presented by Seaman (1977) and were adapted from Hubbel and Glenn (1973). In the marine portion, from the mouth to river mile 7, the generalized sediment type was a silty sand. In the transition zone, from river mile 7 to 23, the generalized sediment type in the flats was a medium sand. In the lower river, the flats consisted of very fine sand. Seaman (1977) also cautioned against overinterpretation, as a detailed map of the estuary, showing distribution of sediments by dominant type, cannot be constructed due to insufficient data and the dynamic nature of the estuary. The marine, transition, and riverine zone boundaries described above were for an average low flow situation. Their actual position varies with daily, monthly, seasonal, and annual fluctuations of tides, weather, and river discharge. A substantial data base on the distribution of sediment in the estuary is being developed for the CREDDP by the University of Washington.

Figures 4.10 and 4.11 present the ecosystem models for the mudflats and the sandflats. The models are essentially as presented in the CPCR and are very similar to one another. Since there is a higher concentration of organic material in the mudflat, that model emphasizes the consumer and decomposer biological community more strongly than does the sandflat model. Wrack import is noted for the intertidal mudflats and is another source of food to the decomposers. The estuarine water column is as described in Section 4.3. Anadromous fish, which move through the estuary, are concentrated in the channels as upstream migrating adults, and over the nearshore flats as downstream migrating juveniles. The river and oceanic flows are as discussed in Section 4.3 and determine the estuarine water column characteristics, although these may be altered over the flats through solar heating and biological processes. Mixing and sediment moving by wave action are significant in shallow areas. The atmospheric processes are as described in Section 4.2.

Components of the ecosystem models discussed in the following subsections are noted in the models by the given numbers: heat (1), inundation (2), community composition (3), fisheries and bait harvest (4), log storage (5), dredging (6), pier construction (7), and impacts of energy facilities (8).

4.5.1 Heat (1)

The temperature and dissolved oxygen data for the estuary, as summarized by Envirosphere (1980), does not permit separation of the effects of solar heating of exposed flats from the effects of respiration of benthic biota. Further, during the summer, the incoming river water is quite warm, while the ocean water is considerably cooler. Differences in dissolved oxygen between these source waters are also common.

4.5.2 Inundation (2)

Inundation of flats occurs from changes in the tide, river flow (as flows are regulated by the Columbia River System and released at Bonneville Dam), atmospheric pressure, and regional winds. Low atmospheric pressure accompanied by strong winds from the southwest can increase the water level within the estuary, often resulting in greater freshwater storage. Flooding may inundate riparian habitats as well as the intertidal flats of the

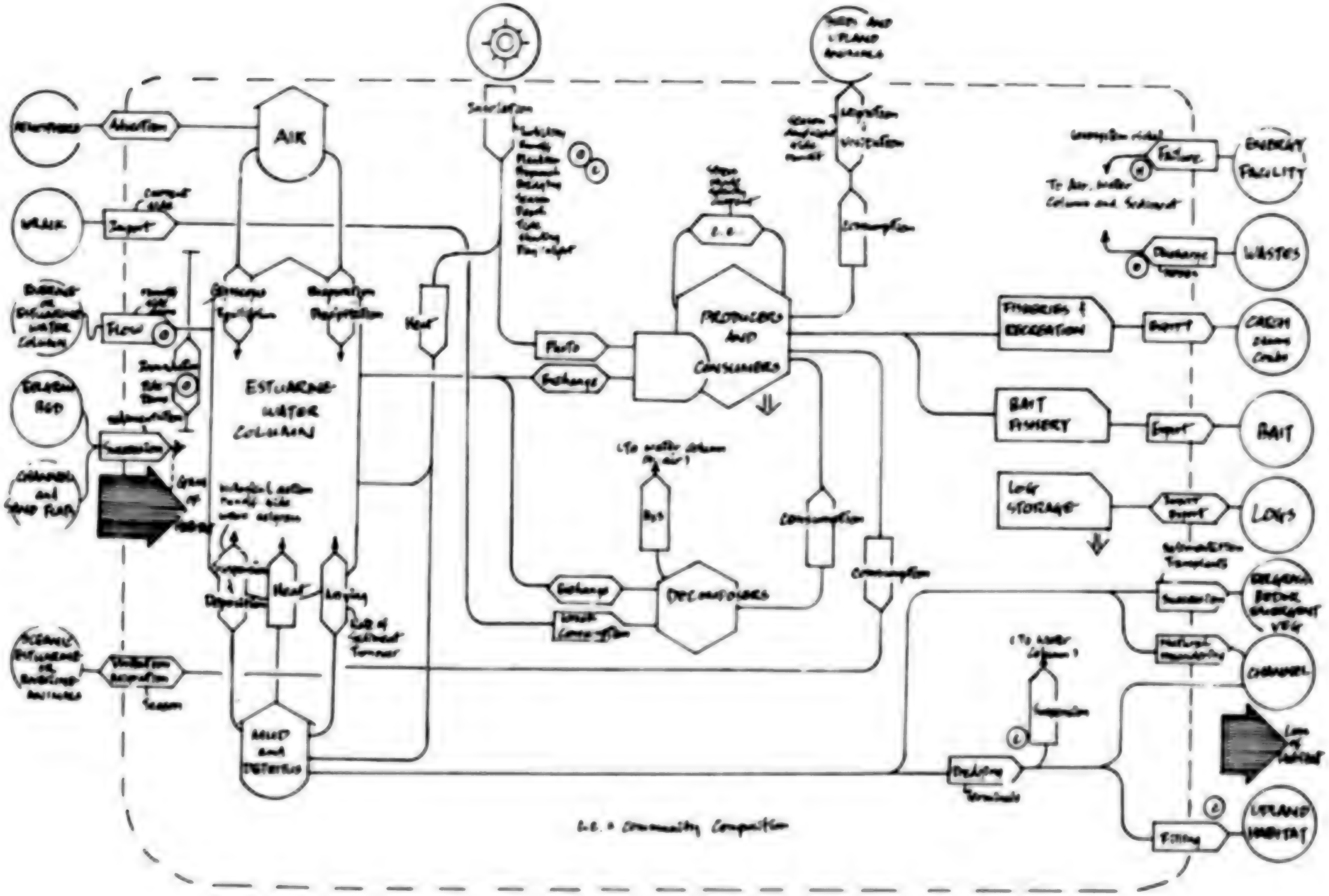

Figure 4.10. Mudflat ecosystem model.

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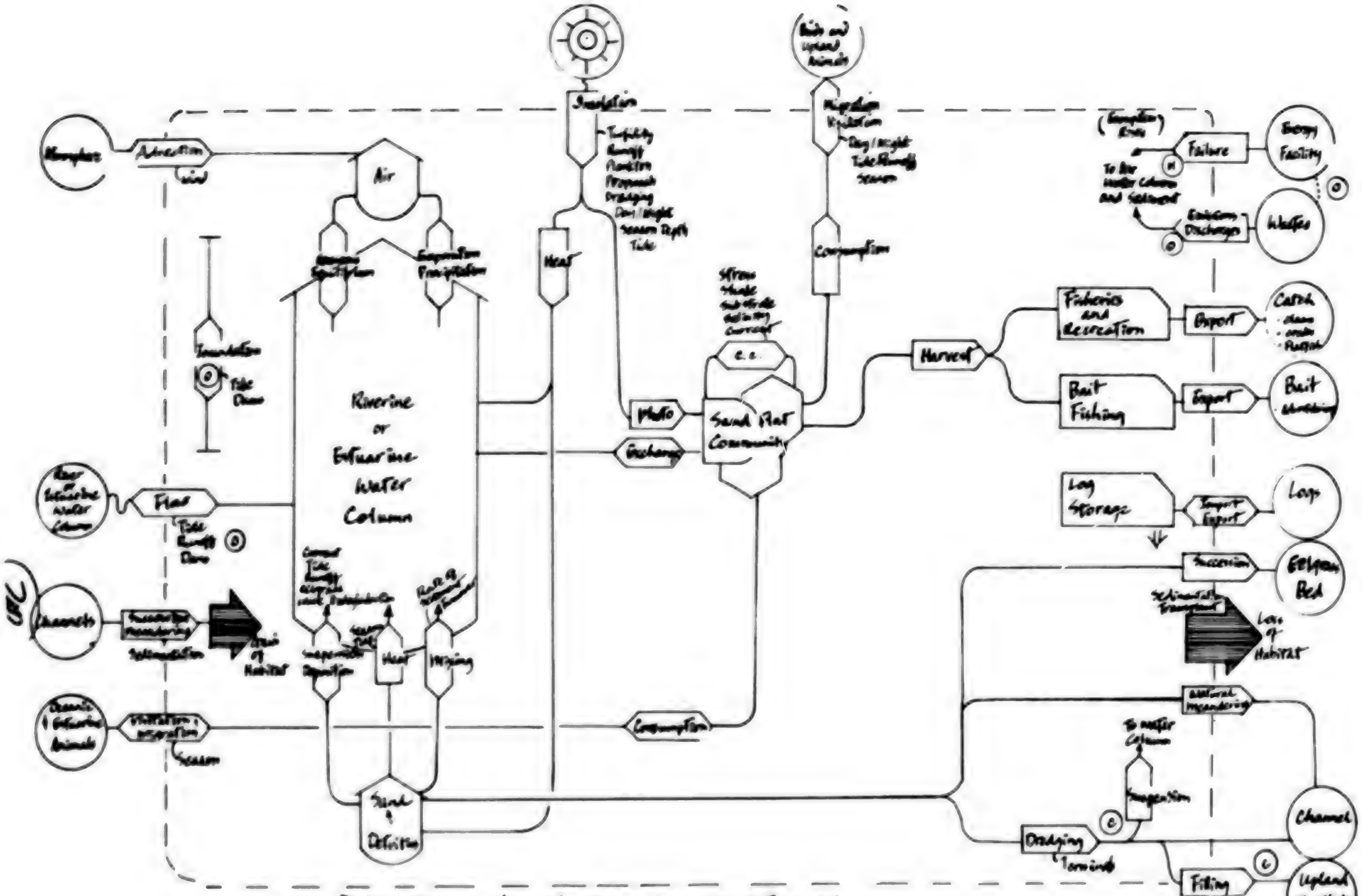

Development may also add pilings - see appropriate model.

Figure 4.11. Sandflat ecosystem model.

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estuary. Approximately 100 km^2 of the Columbia River Estuary (or a little more than one fourth of its total area) is intertidal.

4.5.3 Community Composition (3)

Community composition lists are presented in the CPCR, Vol. 3 for subtidal mudflats (pg 2.1.1A-2), subtidal sandflats (pg 2.1.1C-2), and intertidal mudflats (pg 2.1.2B-2). Within the Columbia River Estuary, there are also distinct biological communities associated with marine, mixing, and riverine zones, and these zones vary in location by river flow, tide, and season as described earlier. The intertidal communities differ from the subtidal in that shorebirds and upland animals visit the community to forage during low tides. Detritus and deposit feeders are less abundant on the high wave energy sandflats, partly because there is less organic matter concentrated there. As the sandflats increase in sediment coarseness, benthic populations and organic matter typically decrease.

4.5.4 Fisheries and Recreation (4)

Humans use the flats for sport and commercial fishing, and the animals harvested include clams, crabs, fish, and bait species. This harvest is usually of minor consequence to these populations. Chapter 5 discusses species of concern to fish and wildlife, some of which make use of the flats.

4.5.5 Log Storage (5)

Log storage over the subtidal flats occurs near the side channels and the shore in Grays Bay and Cathlamet Bay as well as in the tributaries and sloughs. Log rafts are tied to pilings. The pilings and log rafts combine to form a shaded habitat preferred by some species. Log storage also increases the organic content of the sediment, locally, with bark and water-logged wood fragments.

4.5.6 Dredging (6)

Channel dredging and the disposal of dredged materials may result in a loss of mudflat or sandflat habitat, but at the same time may create an upland habitat of potential value to fish and wildlife (e.g., wetlands). Dredging also increases water turbidity and may degrade water quality locally for the duration of the dredging activity, depending on the characteristics of the dredged material. Impacts of dredging are discussed in Section 3.4.1 and are summarized by Allen and Hardy (1980).

4.5.7 Pier Construction (7)

Pier construction may be a part of an energy or port development and involves placing of pilings into the substrate and building structures on them. Pier construction over intertidal and subtidal flats creates additional piling habitat and shade of possible value to some fish and wildlife, and has minimal adverse effects on the flats. Construction of piers out to the shipping channel also reduces the dredging requirements of a project. The piling habitat is modeled in the CPCR Vol. 3, beginning on page 2.1.2A-1.

4.5.8 Energy Facilities (8)

Direct impacts of energy facilities on mudflat and sandflat habitats occur when dredging or pier construction is required or when outfalls are placed across a flat. Dredging physically removes the habitat and its biota. Spoil disposal smothers existing biota and elevates the flats, thus creating a different habitat. Pier construction creates a firm substrate and a shaded habitat resulting in a change in community composition. The impacts from pollution flowing onto these habitats, either from the adjacent uplands or from the adjacent channel, are potentially severe and large in scale. Flows of treated wastes, thermal discharges, or toxic spills may result from adjacent or upstream marine vessels, terminals, refineries, or generating plants. Oil spills could cover large areas, smother or poison biota, and enter the sediments where the toxic effects may persist for long periods of time. Similarly, other toxins may enter the sediment or biota.

Flow regulation, achieved by construction of main stem dams on the Columbia River, has altered sedimentation patterns within the estuary over the years and presents a very low potential for devastating flooding, if a dam fails. Such a failure would carry much of the sediment and organisms out to sea.

A discharge of oil could coat intertidal flats, and the subtidal, shallow flats could receive significant contamination due to waves mixing the oil into the water column and the sediment. Because the flats are natural depositional environments, the wastes are likely to remain within the sediment, interacting with the biota, for many years. Consequently, the oil spill contingency plan developed by Sutherland (1979) is especially oriented towards placement of diversion booms to keep oil out of the major bays, thereby protecting their extensive tideflats.

There will be very little change in the total amount of flats within the estuary attributable to the predicted energy related developments described in Chapter 2. The principal impacts to the flats arise from the hazards associated with existing and proposed energy related developments, such as spills of oil or other toxic substances. Contingency planning and adequate supplies of prepositioned materials for protection of the biologically important flats (and other areas of concern) can effectively reduce the impacts if deployed in time.

4.6 EMERGENT VEGETATION ECOSYSTEM MODEL

Compared to many other estuaries, the extent of emergent vegetation (intertidal) in the Columbia River Estuary is limited. Not only has the community been historically scarce in the region, but also much of it has been altered by diking, filling, and other land use changes. Thomas (1981) has determined that the intertidal marshes of the estuary are mostly palustrine, as defined by Cowardin et al. (1979). They have a salinity of less than 0.5 ppt. Estuarine marshes only occur in Trestle and Baker Bays. Salt marshes are nonexistent. The total area of marsh in the estuary up to the east end of Puget Island is approximately 5,700 ha (Thomas 1981), which is about 15% of the estuary.

Marshes are ecotonal communities between terrestrial, riverine, and estuarine environments. They contain a mosaic of species from all three environments. Marine, estuarine, and riverine species are more common at the outer fringes of the marshes and channels, while terrestrial species are found in greater numbers farther inland. Many species move in and out of the area with the tide and runoff fluctuation. Marsh vegetation is principally vascular and herbaceous although algae are also common and play an important role in productivity. Freshwater marshes occur along the Columbia River from about river mile 10 in the estuary to the east end of the study area (Portland); the model, Figure 4.12, is descriptive for these as well.

There is presently conflicting information on the role of marshes as a source of energy and food, through detritus export, for the river and estuary at large. Estuarine ecologists are now reevaluating whether marsh communities act as nutrient and sediment traps.

Net productivity is high, with estimates from CREDDP studies by SAI, Inc. and Woodward-Clyde (1981) ranging from 300 to almost 2,000 g dry hot/m^2/yr at different sites. In this region, this does not appear to be as great as the inland seral forest production.

Producer biomass is considerably less than inland forest communities yet greater than most marine or estuarine communities. The small biomass to high productivity ratio is indicative of the rapid nutrient cycling and exchanges of this community.

Marshes are subject to pulsating environmental conditions based on tidal cycles, release of water at Bonneville Dam (varies with power peaking), daily and seasonal cycles, and periodic storms and floods. Such patterns require the inhabitants of the marsh either to be adapted to fluctuating salinity, temperature, gaseous conditions, and periodic inundation, or be able to migrate in and out of the area.

Productivity is modulated by daily, seasonal, and tidal cycles. Detritus export likewise is linked to water exchange and storm conditions. Community composition changes with seasonal visitation by vertebrate species and seasonal shifts of abundance and biomass of the producers and invertebrate consumers.

In its natural state, little, direct human use of measurable marketable value is made of marshes. Grazing and waterfowl hunting occur in

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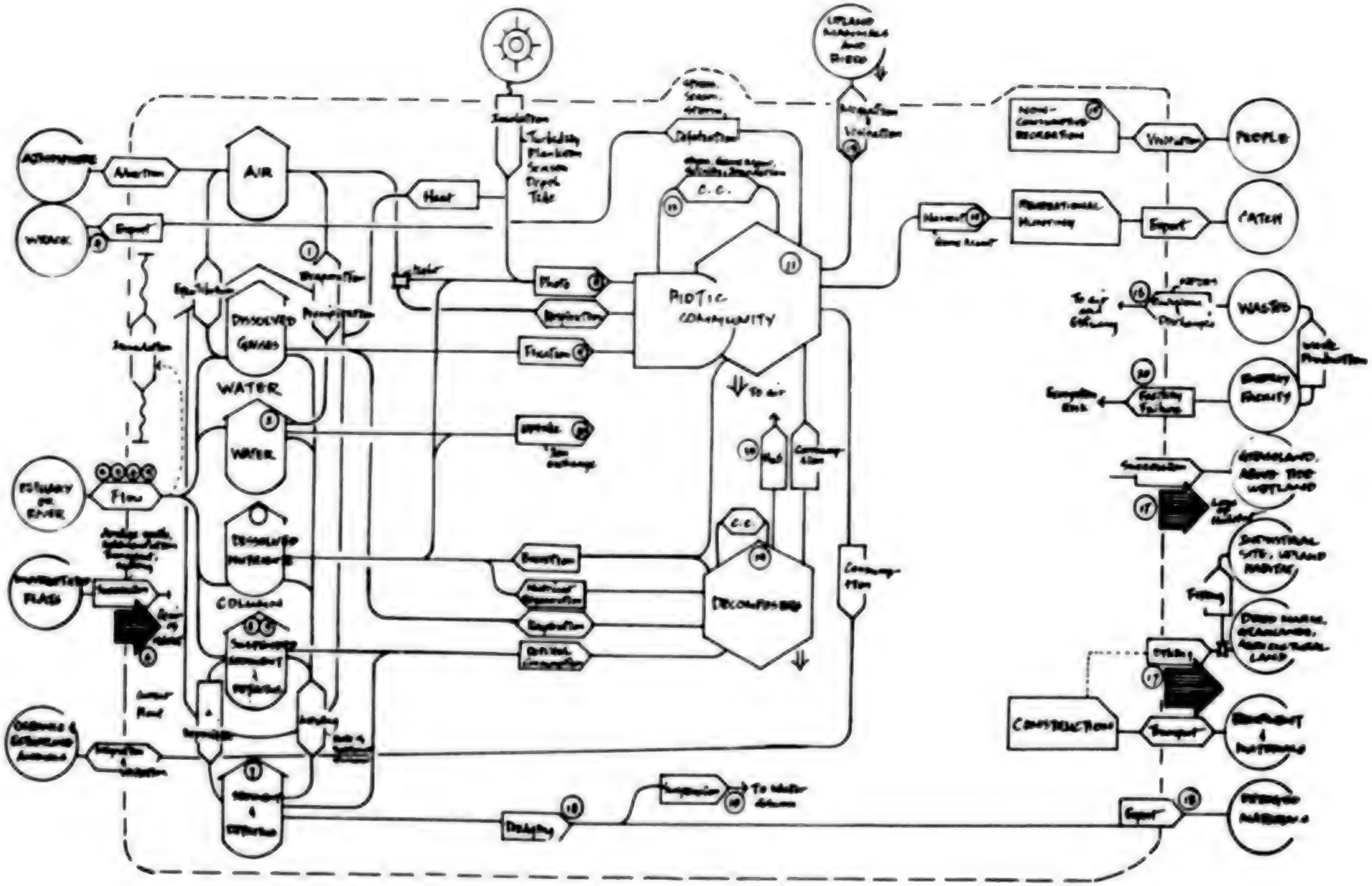

Figure 4.12. Emergent vegetation energy model.

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them, along with some nonconsumptive uses such as bird watching. Diked and filled, the marshes are used for agricultural production and/or development of shipping, housing, energy facilities, or other similar facilities (human activity zones). Only recently have people gained an appreciation of the resource values of marshes in the ecosystem.

Marsh vegetation may be of considerable significance in primary production in the lower river and the whole estuary system. The marsh also provides mitigation of floods and sedimentation, as well as potential value in waste treatment. It enhances the ability of the estuary and lower river to accept certain waste products. Being a distinctive and regionally scarce environment, protection of emergent marsh and other vegetation habitat is required to maintain environmental diversity in the estuary.

Major components, processes, and relationships of the emergent vegetation ecosystem and energy-related developments are modeled in Figure 4.12. These are discussed in detail in the following subsections and are referred to in the model by the given numerals.

4.6.1 Water Input and Output (2)

Emergent marshes experience a rapid exchange of water and suspended and dissolved materials with the adjacent river or estuary. This exchange of water and materials has significant effects on productivity and decomposition. Marsh conditions are strongly related to river discharge and tidal conditions which determine the periods of submergence and exposure. Maximum tidal fluctuation typically occurs during spring tides in June and December. Freshwater flow through the estuary peaks with spring melt (CPCR, Vol. 2, Figures 2 - 20). The height and duration of flooding has been significantly reduced by upstream dams (CPCR, Vol. 4 Watershed Unit 3, Tables 1-2). Morphology of adjacent channels, atmospheric pressure conditions, and coastal storm surges also affect the water exchange and currents. Some wetland studies outside the region have documented a strong correlation between tide strength and net primary productivity (Odum 1974). As indicated in the model Figure 4.12, the marsh vegetation physically resists current flow, buffers movement of water in and out of the environment, reduces local currents (Eilers 1975; Ranwell 1972), and increases sedimentation. This buffering at times of flood and storm tides can mitigate both erosion and property damage (Akins and Jefferson 1973).

Water circulates through marshes by creek systems which in the Pacific Northwest are typically dendritic and are characterized by well defined main channels with numerous minor branches and subbranches. This type predominates in the bays of the estuary, and in Baker, Grays, and Youngs Bays, (Eilers 1975). Marshes of higher gradient conditions have very simple drainage patterns and predominate in other portions of the estuary. The drainage pattern infrequently penetrates into the high marsh above 2.76 meters (9.05 feet) above mean lower low water (Eilers 1975).

In various bays, marsh creeks can be hydrologically divided into higher order creeks of the lower marsh, which have high velocities in both directions, and low order creeks of the higher marsh, which have significant flow velocities in only one direction (Paestrong 1965). Unidirectional flow in low order creeks occurs during the ebb tide cycle when a greater hydraulic gradient is caused by a delay in drainage of the marsh due to friction and a rapid decline in the height of bay waters (Paestrong 1965). Additional information on profiles and cross sections of marshes is given by Eilers (1975) and Thomas (1981).

Ditching of marsh land has been carried out in the past to increase drainage to permit usage for agriculture, most often grazing of cattle. The dropping of the water table following ditching can cause significant reductions of abundance and diversity of invertebrate species and substantial changes in chemical conditions of the marsh.

4.6.2 Nutrient Input/Output (3)

Estuarine marshes are thought to trap and recycle nutrients (Ranwell 1972). The trapping is accomplished in part through the many exchange sites typical of the fine clay particles of salt marshes (Odum 1970). The high organic contents of salt marshes also form organic colloids which have high adsorptive capabilities for trapping nutrients (Albrecht 1941). Many of the nutrients so captured are accumulated and incorporated into biomass. Nutrients flow through onsite food webs and may also be exported to adjacent habitats as detritus. The significance of detritus export from the Columbia River Estuary marshes is still not clear. Numerous studies, not specific to the Columbia River or its estuary, have indicated that marshes, by removing nutrients from the water, effectively can provide a tertiary treatment step for both natural and man-derived wastes that may enter the system through either point source discharges (such as sewage treatment plant outfalls) or nonpoint sources (Gosselink et al. 1973; Windom 1977).

4.6.3 Input/Output of Detritus and Other Dead Organic Material (4)

Marshes are net exporters of organic material and have been documented to provide an important contribution to the energy base of adjacent habitats (Odum and de la Cruz 1967; Eilers 1975). However, within the lower Columbia River and its estuary, the importance of this detritus export is not clear. CREDDP studies of emergent plant production have estimated annual net carbon production for marshes west of Tongue Point at 430 g $C/m^2/yr$ and east of Tongue Point at 348 g $C/m^2/yr$ (SAI and Woodward-Clyde 1980). Marsh mapping by Thomas (1981) indicates there are a little over 700 ha of marsh west of Tongue Point and a little less than 5,000 ha of marsh east of Tongue Point (to the west end of Puget Island). Assuming that all of this net carbon production is available to the estuary as detritus, a total of 2×10^{10} g C/yr are potentially available. These estimates are based on preliminary data, and do not include those portions of the study area east of Puget Island. Unknown factors of importance in evaluating the detritus include: 1) residence time of detritus in the estuary (especially since detrital export from marshes is likely to be greatest during spring or summer freshets, when residence times may be the shortest); 2) percentage of carbon actually incorporated into the marsh soil; and 3) comparison of the marsh detritus input with other sources (such as tributaries, litterfall, outfalls, and the ocean).

SAI and Woodward-Clyde (1980), in their annual report to CREDDP stressed the needs for a program to "elucidate the fate of detritus material in the estuary and determine the amount of plant material produced in the emergent marshes that is actually used within estuarine food chains."

4.6.4 Sediment Input/Output (5)

Marshes can be sediments traps. They are typically found in a low energy environment with a low gradient, which often allows settling of imported sediments.

Sediment deposition is affected by seasonal changes in runoff (as regulated by main stem dams), tides, and coastal wave driven transport processes. Sediment normally accumulated during the lower river flows were carried out of the estuary during floods or freshets. The normal balance, or rate of accretion (whichever was the case), has been greatly affected by the flow regulation by the main stem dams, such that the removal of accumulated sediments by freshets has been greatly reduced. Jetties at the river mouth inhibit the movement of marine sediments. Seaman (1977) estimates the present shoaling rate of the estuary at 15 percent per century, which surely represents an adjustment to the man-made changes on the river flow. Estuary shoaling may lead to an increase in marsh habitat.

Emergent vegetation physically reduces currents, thereby increasing sedimentation, and the roots reduce scour and erosion of sediment. Relationships between current, sediment size, and deposition are given in CPCR Vol. 1, Sec. 2.5.4.

Settlement, compaction, and decomposition of organic bulk can occur, in some cases resulting in a semipermanent marsh with a near stable elevation (Stearns and McCreary 1957).

Deposition of sediments in channels raises the elevation of the water surface, thus imposing an increased hydraulic gradient with regards to down stream or adjacent estuarine areas. Such a gradient in conjunction with the influence of gravity causes the flow to take the most direct route, thereby invariably causing a migration of the channel (Percy et al. 1974). Maintenance dredging prevents shifting of navigation channels.

Shifting channels through marshes can in turn cause a significant turnover of sediments. Eilers (1975) and Paestrong (1965), however, report that channel migration is largely restricted to lower portions of the marsh and adjacent mudflats, as vegetation stabilizes and fixes the meanders in upper reaches. Eilers (1975) does report some caving and undercutting occurring within the marsh, but that the channel configuration remains fairly fixed.

4.6.5 Gain of Habitat (6)

Because the estuary is accreting, marsh habitat will be added to at the waters edge. This gain of habitat is countered by succession, diking, ditching, and filling.

4.6.6 Marsh Soil (7)

In contrast to high, infrequently submerged marsh soils, the aerobic layer of frequently submerged low marsh soils is three centimeters (1 inch) or less thick. This is due to the fact that oxygen and other gases can only enter from the water above, as diffusion in interstitial water is a thousand times slower than in the gas filled pores of high marsh soils (Darnell et al. 1976). The typically fine, low-bulk soils of marshes are largely anaerobic, because oxygen is removed by the decomposition of organic matter faster than it can be replenished. These anaerobic soils maintain chemicals in a reduced state. Decomposition within the soil proceeds slowly with a large variety of intermediate unoxidized decomposition compounds (e.g., organic acids, aldehydes, alcohols, amines, mercoptans, methane, hydrogen sulfide, and others) (Darnell et al. 1976). Some of these products (e.g., hydrogen sulfide, methane) are toxic to organisms (Smith and Oseid 1971; Smith 1971; Darnell et al. 1976; OSU 1977). For more information on decompositon, see discussion in Section 4.6.10.

Typically, reduced compounds are very water soluble and could be expected to diffuse to the overlying water. However, the oxidized surface layer is an effective barrier between the reduced layer and the water column. Root systems are able to extract nutrients under these conditions.

Increased elevation, or lowered water table, enhances leaching and oxidation. The resultant acid conditions adversely affect crustaceans and molluscs which depend on alkaline conditions for shell building. Under anaerobic conditions, sulfates are reduced to sulfides in the presence of organic matter. The sulfides combine with iron in the clay to form polysulfides where they remain if the soil remains wet. If the soil dries and becomes aerobic, the sulfides oxidize to form sulfuric acid and can drop the pH to 2.5 or less (Neely 1962).

Emergent marshes in natural conditions are an ecotone environment having gradient conditions. For example, salinity in a marsh is typically equal to that of the available source at the lower and middle elevations and increases (from evaporation) at the upper extremity during dry seasons, before dropping to near zero above tidal influences (Hedgpeth 1978). Similarly, Eilers (1975) reports a decline in soil salinity with depth in the high marsh, thought to be caused by the upward movement of water due to evapotranspiration. Likewise, soil oxygen decreases with depth. Table 3-14 in the CPCR Vol. 2 provides the extreme ranges of conditions which can be expected on an emergent marsh. The gradient conditions are extremely complex as variable tidal fluctuations establish daily, monthly, and annual cycles modified by flooding influences. Where marshes are diked, the gradient is removed, and soils show a marked change in conditions.

4.6.7 Photosynthesis/Productivity (8)

Estuarine emergent marshes are generally considered to be highly productive communities (Odum 1971) and are typically more productive than the adjacent sea or uplands. The causes of their relatively greater productivity, as summarized by Odum (1971), include replenishing and recycling of nutrients, multiple producers programmed for year-around productivity using substrate and water as nutrient sources, and tidal actions which subsidize productivity by transporting food and nutrients. Additional factors described by other authors include: an increased growing season (Keefe 1972) caused by buffering of thermal effects by estuarine water; vertical orientation of the leaves of salt marsh species which maximizes the leaf surface to sunlight ratio, reduces shading, and decreases intense heating of the leaf surface (Palmer 1941; Jarvis 1964); and availability of moisture and high concentrations of organic colloids which aid in the uptake process (Albrecht 1941; Keefe 1972).

Salt marsh productivity studies have been completed by Hoffnagle and Olson (1974), Eilers (1975), and Hoffnagle (1976) within the region, with additional studies by Northwest Environmental Consultants (1975) and Burg et al. (1975) for nearby marshes within Puget Sound. Productivity data from the Pacific Northwest are presented in Sec. 3.2.1.2 of CPCR Vol 2. Productivity of salt marshes in areas outside the Pacific Northwest has been summarized by Eilers (1975) and, with some additions, was also presented in Sec. 3.2.1.2 of the CPCR Vol. 2. SAI Inc. and Woodward-Clyde Consultants are currently studying emergent plant production at 22 stations in the estuary. Their studies include above ground vascular plant biomass, decomposition, percent cover of different species, and below ground (root) biomass analysis. Preliminary analysis of productivity and decomposition studies have been conducted (Envirosphere 1980). Eilers (1975) reports a relationship between elevation and productivity. However, other studies (Burg et al. 1975; Northwest Environmental Consultants 1975; Vanderzanden et al. 1976) have indicated an opposite trend, with the mature high marsh (or diked marsh) being least productive and *Carex* or *Juncus* marshes being typically most productive. The ongoing studies for CREDDP have indicated that the low marsh was more productive than the high marsh for stations west of Tongue Point. East of Tongue Point the low marsh productivity decreased to where it was less than the high marsh. Estimated annual net above ground vascular plant production for 22 stations in the Columbia River Estuary are presented in Table 4-16.

Review of these studies indicates that productivity in different portions of an emergent marsh differ markedly, that there is a considerable difference in the value of production to the estuary as some species have different nutritional qualities, and that export to the estuary differs widely.

One of the most productive portions of the salt marsh appears to be the *Carex* marshes (Vanderzanden et al. 1976; Northwest Environmental Consultants 1975; Eilers 1975; Burg et al. 1975). *Carex* occurs in the intertidal areas where it can be readily exported and rapidly decomposed.

Table 4-16. Estimate of annual net above ground vascular plant production.

Sample sites - station	Marsh type[a]	Estimated production values[b]
Baker Bay-China Cove, *Carex*	LM	630.2 (76.3)
Baker Bay-China Cove, *Scirpus*	LM	472.5 (94.6)
Baker Bay-Ilwaco	LM	845.7 (89.0)
West Trestle Bay	LM	600.5 (86.0)
West Trestle Bay	UM	817.7 (67.7)
East Trestle Bay, *Carex*	LM	1730.1 (200.6)
East Trestle Bay	LM	781.3 (104.7)
East Trestle Bay	MM	899.9 (108.2)
East Trestle Bay	UM	771.5 (76.4)
Youngs Bay-Outer	LM	1969.1 (341.9)
Youngs Bay-Inner	LM	991.4 (173.9)
Army Corps Dock	LM	902.2 (181.5)
Lois Island	LM	310.8 (82.4)
Grays Bay-Inner	UM	391.4 (69.4)
Grays Bay-Inner	UM	892.6 (105.2)
Grays Bay-Outer	LM	640.9 (113.7)
Grays Bay-Outer	UM	820.4 (87.3)
Russian Island	UM	1094.0 (94.8)
Karlson Island	LM	576.4 (87.6)
Tronson Island	UM	591.4 (95.7)
Quinns Island	LM	777.7 (156.1)
Puget Island, *Typha*	LM	1501.5 (283.7)

Source: SAI, Inc. and Woodward-Clyde (1981) and Envirosphere (1980).

[a] LM = Low Marsh, MM = Mid-Marsh, UM = Upper Marsh.

[b] Values listed represent mean value with standard error in parentheses. Units = g dry wt/m^2/yr. Totals represent sum of live weight attached standing dead. Attached standing dead represents present year's growth. Litter not included in totals.

It compares favorably to other salt marsh species as a food source in controlled experiments with mussels and oysters (Eilers 1975; Hall 1976; Gnat et al. 1976; Stunz 1976).

There is also a seasonal component to productivity. Biomass increases over time, as indicated in Figures 3-21 and 3-22 in Vol. 2 of the CPCR and provides evidence of differential productivity as well as different peaking periods for different associations. Figures 4.13 and 4.14 show standing crop biomass for the Columbia River Estuary marshes for April and July, 1980, respectively. The biomass of most species peaks in July, although best grass and seashore salt grass have later peaking dates.

The preceding information has not included root production which makes up the majority of the standing biomass of the salt marsh species of the region (Vanderzanden et al. 1976). A study in Mississippi by de la Cruz and Courtney (1977) documented root production (970-1,240 g/m^2/year) comparable to annual aerial production in an emergent salt marsh, with the majority of the production occurring in the top 20 centimeters (8 inches) of soil.

In addition to the productivity of the macrophytes which are discussed above, periphyton and benthic diatom productivity make up a significant but regionally undocumented portion of the salt marsh net primary productivity. In a Louisiana study, benthic diatom, phytoplankton, and epiphyte production made up nearly 40 percent of the net primary productivity of a salt marsh (Day et al. 1973).

4.6.8 Community Composition (12)

The emergent vegetation (marsh) community is an edge community that occurs where the shoreline interfaces with the estuary. Some organisms are characteristic of both environments, and salt tolerant plants (halophytes) have adapted to the special conditions and are specific to the community. The marshes of the Columbia River and estuary differ from other regional marshes in that the tidal waters are fresh or only slightly saline. The community composition for emergent vegetation was presented on page 2.1.2C-3 in Volume 3 of the CPCR and is applicable here. Thomas (1981) recently inventoried the marshes of the estuary and identified 19 different marsh types according to vegetation dominance. Types 2, 3, 4, 6, and 7 are common to the islands in Cathlamet Bay, and types 9, 10, 11, 12, and 18 are common to the lower estuary shoreline.

4.6.9 Migration (13)

Many migratory consumer species use the marshes. Shiner perch and staghorn sculpin enter and leave with tidal waters (Hoffnagle 1976). Other species exhibit nocturnal usage, such as the raccoon which leaves the marsh for shelter during daylight hours. Others are seasonal visitors, waterfowl and raptors being the most obvious. Still others (e.g., juvenile salmonids and Dungeness crabs) may use the marsh during only a portion of their life cycle.

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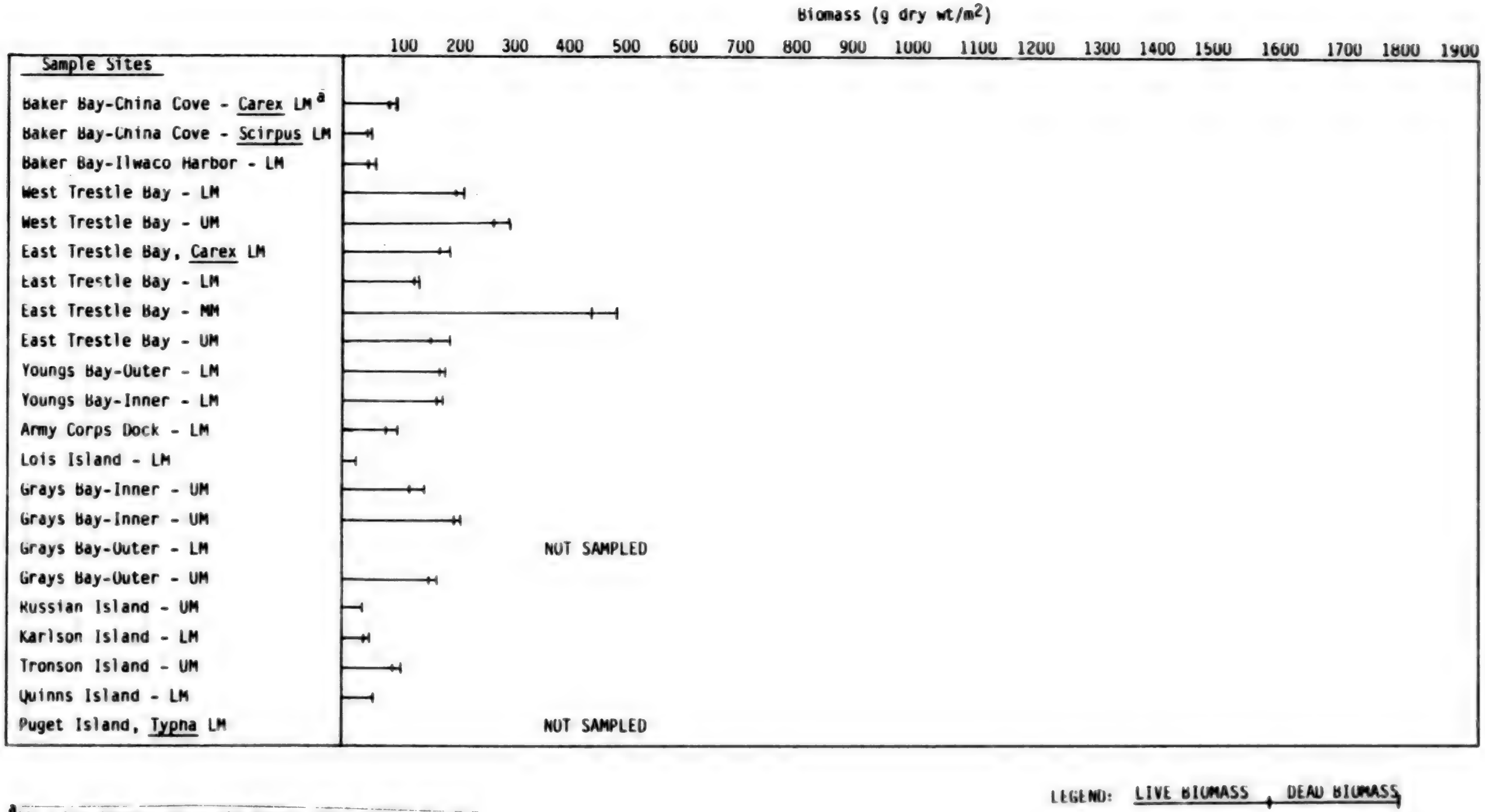

[a] LM = Low Marsh, MM = Mid Marsh, UM = Upper Marsh

Figure 4.13. Biomass of above ground vascular plant material in April 1980; biomass includes weight of live plant material plus attached dead plant parts (leaves) produced during this year's growth. [From SAI, Inc. and Woodward-Clyde 1981 (CREDDP Annual Report For 1980)].

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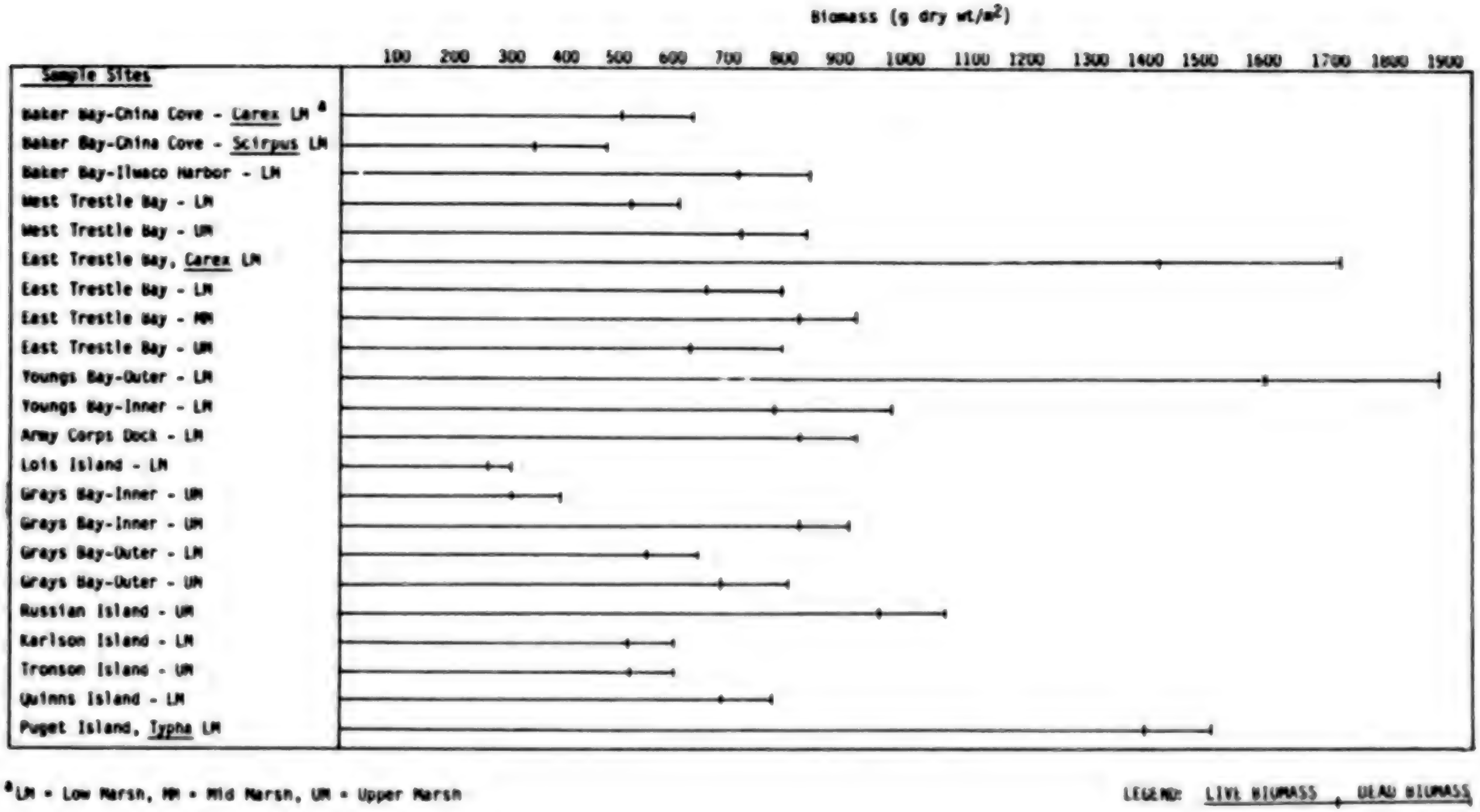

Figure 4.14. Biomass of above ground vascular plant material in late July 1980; standing crop biomass includes weight of live plant material plus attached dead plant parts (leaves) produced during this year's growth. [From SAI, Inc. and Woodward-Clyde 1981 (CREDDP Annual Report For 1980)].

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4.6.10 Decomposition (14)

In the high marsh, decomposition is primarily aerobic in surface and subsurface soils, and organic materials are decomposed rapidly onsite (Eilers 1975). Periodically, oxygen levels may decrease during seasonal high tides and/or flooding.

Accumulation of litter appears to occur in the transitional areas between the lower marsh where detritus is thought to be exported and the upper marsh where aerobic, dryer conditions allow for more onsite rapid decomposition.

SAI Inc. and Woodward-Clyde evaluated decomposition rates in marshes in the estuary (Envirosphere 1980) and found that comparable plant materials decompose more rapidly at upriver stations than at downriver stations.

4.6.11 Human Use (15)

There is only limited direct use of the marshes of the region. Although very little documented data are available, most of the waterfowl hunting occurs in this habitat. Bird watching and nature study follow closely in amount of use. Some domestic cattle grazing occurs on Sand Island in the Columbia River Estuary. Marsh detritus may be of importance to commercially significant species in the estuary. De la Cruz (1976) has reviewed various other human uses which marshes can provide, for example, sewage assimilation and aquaculture.

4.6.12 Pollutant Input (16)

Estuaries and marshes in particular are considered to be sites where pollutants accrue (Woodwell 1967; Ohlendorf et al. 1974). The accrual of sediments and materials, the intensive biochemical cycling within the estuary, and the intertidal nature of marshes establish this habitat as a location where pollutants can accumulate.

At present, some toxic discharges along the Columbia River have become concentrated in the marshes after being dispersed through the estuarine water column. Point sources include treated sewage, pulp mill effluents, low level radiation, cooling water with chemicals; important nonpoint sources include septic tank drainage and urban and agricultural runoff. There are over 300 known municipal and industrial facilities discharging wastes directly into the Columbia River and its tributaries below Bonneville Dam. Facility names, locations, river miles, volumes in millions of gallons per day, BOD, suspended solids, and other important pollutants released are presented by Seaman (1977). The operations and administration of the NPDES by the USEPA and the states of Oregon and Washington to regulate these discharges and protect water quality have been detailed by Envirosphere (1980). Municipal sewage treatment plants, various industries including pulp and paper mills, and seafood processors, are the major dischargers to the estuary. In the lower Columbia River, the Willamette River, and the estuary area, the timber products industry accounts for 78 percent of the BOD and 69.9 percent of the total suspended solids loading from point sources. Point sources account for approximately 1.1 percent (68,000 tons/yr) of the total annual suspended solids load for the river. BOD loading from point sources is less significant than that from nonpoint sources. Point sources are considered important contributors in terms of the heat budget, radioactive contaminants, heavy metals, and organic chemicals including herbicides and pesticides. Heat contributions from solar heating of the storage ponds behind dams are more significant than the heated discharges of industry (Seaman 1977).

4.6.13 Loss of Habitat (17)

Marshes in this region, as well as world wide, have been reduced in size (and in many places completely eliminated) through diking, filling, disposal of dredged material, and ditching, or some combination thereof. Much of these lands have been converted to agricultural use; some, to waterfront development; and others, to disposal sites. USDI (1970, Volume 1) reports 13 percent of the estuarine area in the Pacific Northwest has had slight modification; 50 percent has had moderate modification; and 37 percent has had severe modifications. A substantial but undocumented portion of these modifications consist of wetland losses. Seaman (1977) estimates 700 acres (300 ha) have been filled in the Columbia River Estuary. In addition, of the 170,000 acres (68,000 ha) of flood plain bordering the lower Columbia River (mouth to river mile 125), 65 percent or 110,500 acres (44,000 ha) are protected by dikes or levees. Obviously, a large amount of wetlands (emergent marsh) has been affected, but precise quantities are unknown. Continued dredging of the lower Columbia River will maintain a demand for spoil sites, some of which are likely to be emergent marshes.

4.6.14 Dredging (18) and Suspension of Materials (19)

Where an energy development requires dredging of marsh, there will be a direct loss of this habitat type, with a replacement by a channel habitat. Dredged materials may be deposited on other marsh habitats, also resulting in habitat loss (note 17). Maintenance dredging of adjacent channels may have a minor impact on marshes in that short-term increases in turbidity may increase sedimentation within the marsh. If there are any pollutants in the sediments which are resuspended in the water column, these will become available to the marsh as well. Sulfides, present in anoxic sediments, may be released to the water column and are toxic to many forms of life (see notes 7 and 14).

4.6.15 Energy Developments (20)

Energy developments occur mostly in riparian habitats bordering the estuary or the river. Facilities such as refineries may generate liquid, solid, or gaseous wastes, some of which are stored, and some of which are released to the environment through emissions or discharges under NPDES permits. Hence, energy facilities will contribute to the total waste loading of the river and estuary (see note 16). Energy facilities may also impose risks on the marshes through a major failure of some component, be it within the facility itself or the transportation facilities concerned with it. High level radioactive wastes are currently stored at the Trojan Reactor site, although that is not intended to be their final destination. If the storage system were to fail through natural disaster, human error, or intentional acts of sabotage or aggression, these wastes could enter the estuary and the marsh environment with detrimental effects. The effects of radiation would be evident in the food chain, where bioaccumulation of radionuclides would occur in some species. This is a principal concern to people who may harvest and consume affected species. Other energy-related facilities, such as storage facilities, marine terminal transshipment facilities, marine vessels at terminals or underway within the estuary or river, or pipelines, may produce oil spills (crude or refined products).

Beak Consultants, Inc. (1975) evaluated the biological impact of oil spillage and developed a general habitat vulnerability ranking system. Coastal habitats were ranked from highest to lowest vulnerability as follows:

Physical Impact	Toxicity Impact
Salt Marsh	Mixed-coarse
Eelgrass bed	Solid rock
Silt	Salt Marsh
Mixed-fine	Eelgrass bed
Mixed-coarse	Kelp bed
Sand	Mixed-fine
Solid rock	mud
Kelp bed	Sand
Open water	Open water

An Oil Spill Contingency Plan developed for the Columbia River and its Estuary by Sutherland (1979), under funding from the Coastal Energy Impact Program (CEIP) of the Coastal Zone Management Act placed a very high emphasis on the identification and defense of marsh habitats.

Beak Consultants, Inc. (1975) also developed a general ranking for plants and animals vulnerability to oil. Ranked from highest to lowest vulnerability, the groups are as follows:

Physical Impact	Toxicity Impact
Birds	Fishes
Molluscs	Annelids
Echinoderms	Molluscs
Grasses	Echinoderms
Algae	Birds
Crustaceans[a]	Mammals
Annelids	Crustaceans
Mammals[b]	Grasses
Fishes	Algae

[a] The outstanding exception is barnacles which are highly susceptible to physical impact.

[b] The outstanding exception is otters which are highly susceptible to physical impact.

4.7 RIPARIAN ECOSYSTEM

Riparian habitats are the most impacted by construction and operation of energy facilities because most generating, processing, storage, and recovery facilities are all built in the riparian and adjacent upland areas. Dams greatly reduce downstream flooding and inundate upstream habitats. This section will deal with the riparian ecosystem in the absence of energy developments. Subsections 4.7.1 through 4.7.9 will then deal with construction, operation, and hazard related impacts of the different types of energy development.

Riparian is defined within the CPCR as "referring to or living in land bordering a stream, lake, or tidewater." The riparian is a water edge habitat generally differentiated from surrounding areas by distinctive vegetation, often subject to periodic flooding. Riparian habitats have a very high edge-to-area ratio (Odum 1978).

Adjacent aquatic and riparian systems influence one another. This interrelationship is most significant on smaller, steeper gradient streams where shading reduces water temperatures, plant roots stabilize stream banks and provide additional cover, and streamside vegetation acts to filter sediment and detritus. Large woody debris influences channel morphology, and the vegetation provides detritus and attracts insects, both of which are significant components of the food web (Meehan et al. 1977). On larger streams and rivers, the temperature moderating effect of shading is reduced, as the ratio of surface area to riverbank length increases. The riparian habitat is important as a buffer between urban, industrial, and agricultural activities and the local aquatic environment.

The basic riparian ecosystem model is presented in Figure 4.15. The following discussion presents information on flooding (1), substrate (2), community composition (3), and nonenergy related human activities (4). Climatic factors (wind, precipitation, and insolation) are as described in Section 4.2. For smaller streams tributary to the Columbia River, microclimate influence of the riparian on water temperatures becomes quite important.

4.7.1 Flooding (1)

The model represents flooding as a two-way exchange of material between the riparian habitat and the adjacent aquatic habitat (estuary or river). Major floods of the Columbia River were presented in the CPCR, Vol. 4, and trends indicate a considerable decrease in the height and duration as a result of the main stem dams. Smaller floods, associated with snow melt east of the Cascades, are also reduced in significance. Winter flooding caused by rain and snow melt west of the Cascades is not as regulated. Flooding in the lower Columbia River and Estuary is further reduced by diking and/or filling of riparian habitats for industrial, agricultural, or dredge material disposal purposes. Reduction of flooding has reduced the riparian area (as defined by exposure to flooding) and has encouraged developments which further reduce riparian habitat for wildlife.

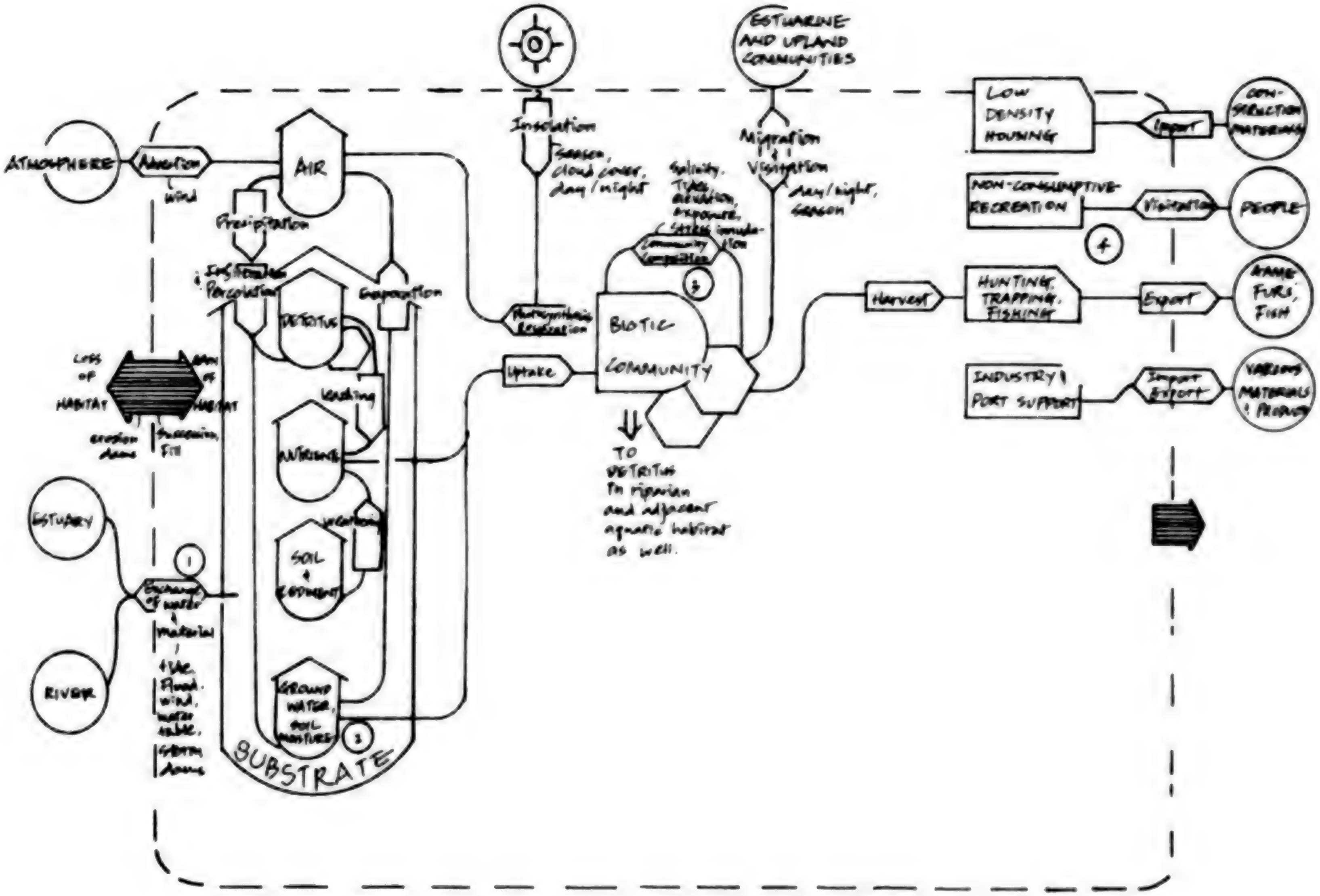
ESTUARINE AND UPLAND COMMUNITIES
ATMOSPHERE
Advection
wind
AIR
Precipitation
Insolation
Season, cloud cover, day/night
Infiltration & Percolation
Evaporation
DETRITUS
Leaching
NUTRIENTS
Weathering
SOIL & SEDIMENT
GROUND WATER, SOIL MOISTURE
SUBSTRATE
LOSS OF HABITAT
GAIN OF HABITAT
erosion dams
Succession, fill
ESTUARY
RIVER
Exchange of water & material
tide, flood, wind, water table, storm dams
Photosynthesis Respiration
Uptake
Community Composition
Salinity, Tides, elevation, exposure, stress inundation
Migration & Visitation
day/night, season
BIOTIC COMMUNITY
TO DETRITUS in riparian and adjacent aquatic habitat as well.
Harvest
LOW DENSITY HOUSING
Import
CON-STRUCTION MATERIALS
NON-CONSUMPTIVE RECREATION
Visitation
PEOPLE
HUNTING, TRAPPING, FISHING
Export
GAME, FURS, FISH
INDUSTRY & PORT SUPPORT
Import Export
VARIOUS MATERIALS & PRODUCTS
1
2
3
4

Figure 4.15. Basic riparian ecosystem model.

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Dam operation has also produced water level fluctuations on a daily, or longer-term basis, for power peaking requirements. As thermal power plants come on-line, the hydropower plants will be utilized more and more for handling peak loads. Additional power houses are being installed at existing main stem dams as the emphasis shifts to peak load generation. Numerous researchers (Stanford Research Institute 1971) have felt that severe fluctuations after sustained flows during nesting and rearing seasons (1 March to 15 June) could cause major waterfowl and shorebird losses and could also result in losses to furbearers during whelping seasons (March to April). Tabor (1976) assumed that tidal effects below Portland would nullify any peaking effect. Because of the uncertainty with regard to the impacts of power peaking and related water level fluctuations, the U.S. Army Corps of Engineers funded a comprehensive study to evaluate these impacts; this was completed by Tabor et al. (1980) and published by the U.S. Army Corps of Engineers in June of 1981. Some of the impacts determined by Tabor et al. (1980) are listed below, for the section of the Columbia River below Bonneville Dam.

Vegetation. Riparian acreage will be reduced. Some species and communities of riparian vegetation would migrate upslope as a result of increased fluctuation but such a migration will not be possible for a large percentage of the shoreline because of man-made alterations (roads, etc.) or natural conditions. Permanent loss of acreage of riparian vegetation may also result from increased erosion of soil supporting riparian vegetation from water level fluctuations.

Avian species. Most of the waterfowl nests were above the predicted operating limits. However, increased erosion of islands will reduce available nesting habitat and nesting activities during the nesting period.

Aquatic furbearers. Predicted mid-1980's water levels from power peaking below Bonneville Dam will have a major detrimental impact on beaver because of: the number of active colonies (more than 15), the large predicted water fluctuations, the high percentage of den sites which will become unsuitable, the increased distances to food supplies during periods of low discharge, and the increased density of potential predators.

Deer. Impacts will be minimal as deer are not as dependent on the riparian habitats below Bonneville Dam as they are further up the Columbia River.

Other mammals. Rabbits and hares will be affected in the spring and gophers and moles will probably be reduced as they would have difficulty inhabiting riparian habitats periodically inundated by high water.

Reptiles and amphibians. No predictions can yet be made on the impact to these animals, as the study design and intensity of sampling were inadequate to demonstrate differences related to water level fluctuations.

4.7.2 Substrate (2)

The riparian is a natural depositional zone, receiving suspended sediments carried by the river during flooding, erosion sediments from the adjacent uplands, and detritus from the biotic community. If the vegetation is removed, the riparian habitat may erode, with excessive material flowing to the stream and altering the aquatic habitat.

The riparian substrate varies with elevation above the stream, river, or estuary due to varying exposure to floodwater, groundwater, and the sediment and nutrients supplied from flooding. Upstream dams reduce the frequency, duration, and extent of flooding, which ultimately reduces the amount of total downstream riparian habitat. Local developments (dikes, seawalls, fill, clearing, etc.) result in additional incremental losses of riparian substrate by local flood control.

4.7.3 Biotic Community (3)

The community composition for riparian habitat of the Western Hemlock Zone was extracted from the translated species list which was developed as an appendix to Vol. 5 of the CPCR and is presented as Appendix B in this report. Slightly different community compositions may occur for the riparian habitat of the Sitka Spruce Zone (river mile 0 to about river mile 5) and the Willamette Valley Zone, defined by Franklin and Dyrness (1973) as starting at river mile 87. Site-specific information may be obtained from Tabor (1976).

4.7.4 Human Activities (4)

Human use of the riparian habitat may be nondestructive, such as recreation, hunting, trapping, or fishing. Low density residential development may locate in riparian areas because of the view and access to the water. Flood control allows construction in riparian areas which formerly flooded. If housing is located within the present floodplain, it may require protection by dikes or fill placement, which further destroy existing riparian habitat. Clearing of land for agriculture may also be detrimental to riparian habitats. Fill placement from dredging destroys existing habitats and brings the fill area above the floodplain, precluding reestablishment of riparian vegetation and encouraging further development. The tremendous volume of sediment deposited in the lower Cowlitz River and at its confluence with the Columbia River following the 18 May 1980, Mt. St. Helens eruption has required extensive filling on adjacent lands.

Port developments and water dependent industries locate adjacent to the river resulting in the elimination of riparian habitats. These developments are presently concentrated near Astoria, Kalama, Longview, Vancouver, and Portland.

4.7.5 Ecosystem Model - Hydroelectric Generation

The impacts of a hydroelectric facility on the riparian and adjacent upland communities are presented in Figure 4.16. Due to the filling of the reservoir behind the dam, a hydroelectric facility impacts the greatest area of any of the energy facilities considered in this study.

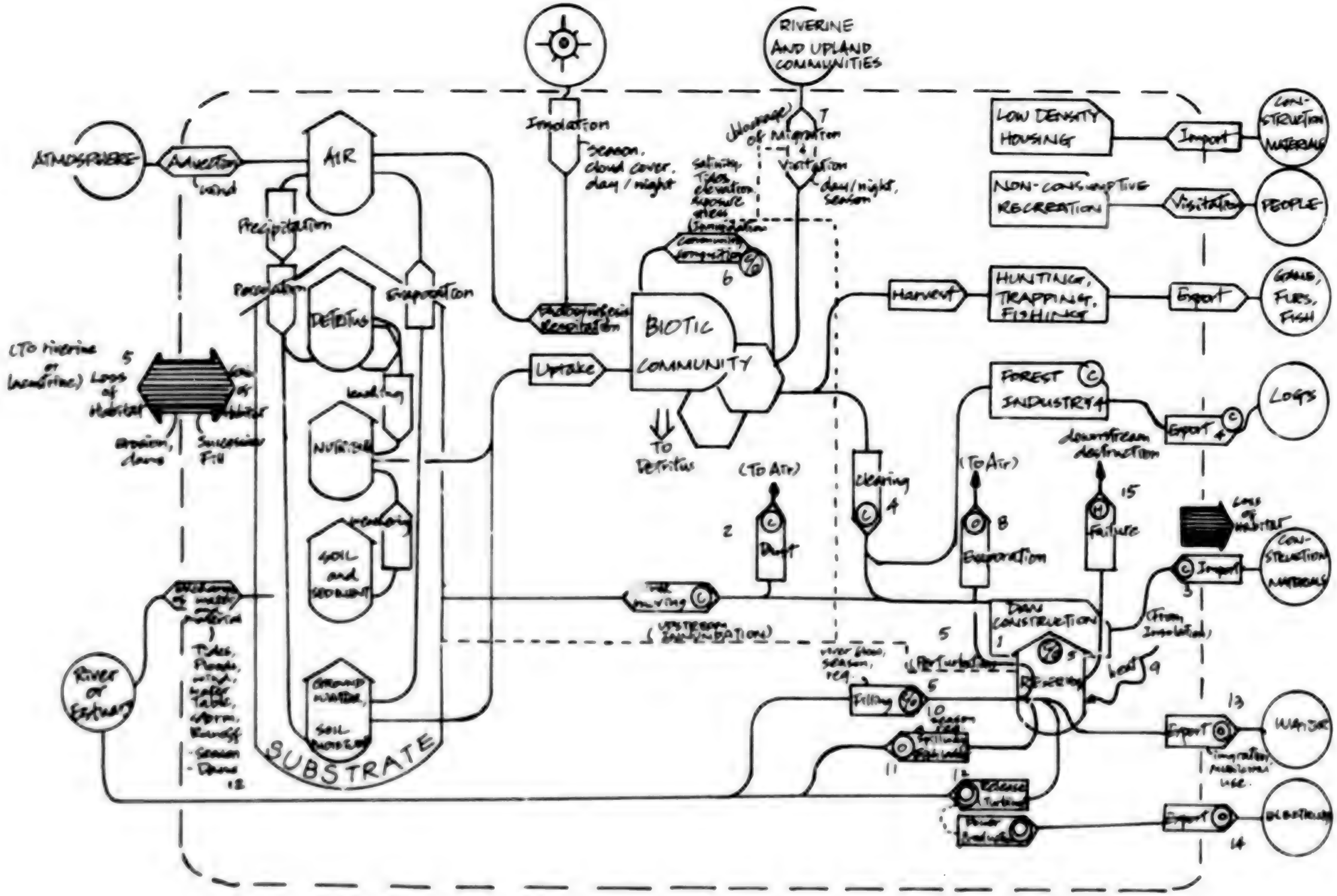

Figure 4.16. Riparian ecosystem model - hydroelectric power generation.

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A hydroelectric facility requires land (1) for construction of the dam and the powerhouses (which may be at the dam or could be at a site further downstream), as well as "borrow" sources of construction materials (3) (rock and earth). Land committed to the reservoir is lost to riparian and upstream habitat (6), and replaced by a lacustrine habitat. This area may be cleared of vegetation (4), with the forest industry exporting marketable timber before inundation. The clearing and subsequent inundation of a large area substantially alters the existing habitat. The use of large earth moving equipment (2) results in considerable dust emission and noise. Animal migration or visitation to the previous habitat will be blocked (7).

Operation of a hydroelectric facility requires periodic changes in reservoir levels. Typically an unvegetated strip rings the reservoir, the width being determined by the average range of fluctuation.

The construction of a dam will also affect the riparian habitats downstream by regulating the flow of the river. The peak floods will be greatly diminished, so the downstream areas subjected to periodic inundation will be diminished. The dams on the Columbia River have already greatly reduced the peak floods both in height and duration (see CPCR Vol. 4).

A reservoir effectively stores water for a period of time before it continues its downhill flow. During the initial filling stage, water flow is significantly reduced. The filling rate allowed must consider what minimal flow is required to support downstream aquatic life, and how that requirement may vary seasonally. Once the reservoir is filled, the annual flow is restored to near its original rate. Water is lost to the atmosphere through evaporation, because of the increased surface area of the water body and the increased wind effects due to the clearing of vegetation (8). Water is also exposed to insolation, producing increases in temperature (9) which can cause the reservoir to become thermally stratified in the summer. The cumulative effect of many dams on a river is to increase the downstream temperature.

Diversion dams block a river flow, channeling it through a pipeline or tunnel to a powerhouse downstream. Potential sites have been identified for diversion dams on tributaries to the Columbia River Estuary. The decision to build such a facility essentially commits the streambed between dam and powerhouse to the project by eliminating (or greatly reducing) the flow. Except for blocking access to spawning beds and loss of rearing habitat of salmonids, diversion dams with small upstream reservoirs have relatively minor impacts, compared to larger impoundment dams.

Unlike most of the other types of energy developments, a hydroelectric facility does not burn fuel and, consequently, there are no hazards associated with fuel spillage or waste products. The risk of possible structural failure of the dam itself is low. Engineering design factors include earthquake activity, bedrock stability, porosity of the rock surrounding the reservoir, and the ability to withstand a rapid increase in upstream flow (perhaps related to failure of an upstream dam or volcanic mudflows). The impacts of such a failure (15) include large scale destruction of downstream habitats.

The hazard of dam failure is lessened with a diversion dam in which the hydraulic gradient is not created by the dam height and reservoir. During the operation of the dam, water may be suddenly released to the dry streambed creating a hazard to people and wildlife. There have been several recent instances in Washington where people were drowned or almost drowned because of this mechanism, and wildlife, unable to read warning signs, are severely affected as well.

4.7.6 Ecosystem Model-Thermoelectric Generating Facilities

The model (Figure 4.17) starts with a basic riparian model showing the relationships between the biotic community and the substrate and air, and the connecting relationships with adjacent riverine or estuarine and upland systems. Human activities that occur within this ecosystem in the study area are mostly hunting, trapping, fishing, or nonconsumptive activities such as recreation or low density housing. The forest industry does not generally harvest the trees in the riparian habitat as they are less desirable and regulations often prohibit such harvesting.

4.7.6.1 Construction impacts. A generating facility requires land for structures, roads, parking lots, and fuel and waste storage (1, 13, 16). This land is physically removed from biological productivity. Construction activities include clearing (2) and large scale earth moving (3), which drastically alter the substrate and affect the nature of the biological community that can become reestablished. Construction alters the interreactions (4) between the riparian and adjacent riverine or estuarine ecosystems, generally increasing runoff from the site and turbidity in the adjacent aquatic system, and decreasing flooding from the aquatic system to the site due to diking or filling above the flood plain. Construction materials (5) are imported to the site and incorporated into the facility. As construction is completed, some impacted land may be returned to biological productivity, either through landscaping or by allowing the natural vegetation to re-establish. The total land owned by the development may exceed the land used for facilities, and buffer zones of natural vegetation may be left.

4.7.6.2 Operational impacts. Plant operation affects the air through emissions (6), evaporation (7), and heat (8). The atmospheric emissions released during normal operations vary depending upon the type of facility. Natural gas fueled facilities release many NO_x; oil fueled facilities release NO_x and SO_x; coal fueled facilities release NO_x, SO_x, and particulates (fly ash); and coal and nuclear power facilities release low levels of radioactivity. Emissions can contribute to acid rains with consequent impacts.

To minimize waste heat disposal to the aquatic environment, generating facilities generally use evaporative cooling systems. The heat and water

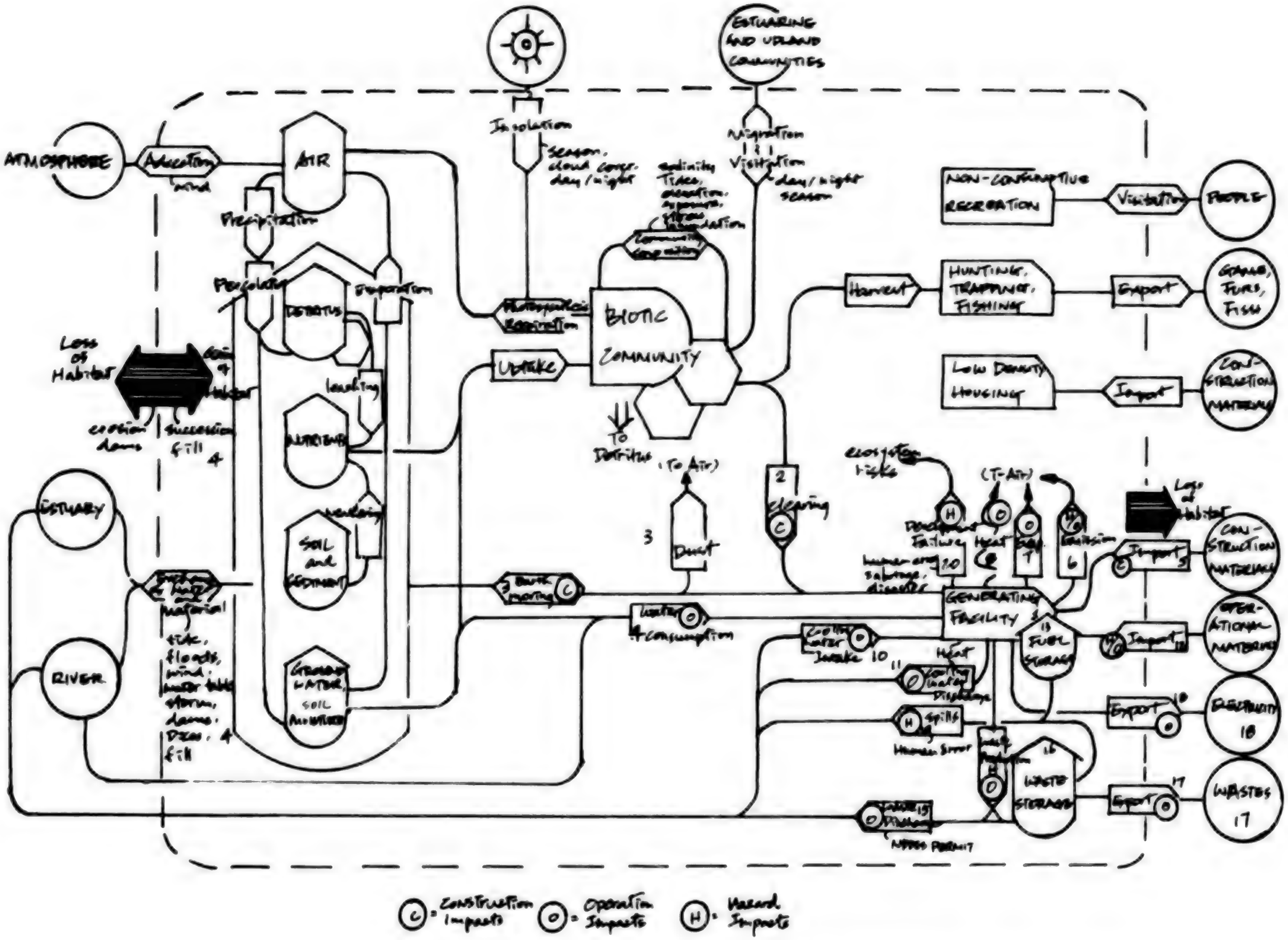

Figure 4.17. Riparian ecosystem model - thermo-electric power generating facilities (fossil-fuel and nuclear).

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vapor dissipated to the air can produce localized climatic effects (clouds, fog, and water droplets).

Because there is a loss of cooling water through evaporation, additional water is required and may be provided from either the river or the estuary (10). Additional freshwater is needed for the boilers and other consumptive uses (9). Although most waste heat is dissipated to the air, some cooling water is returned to the river or estuary (11) carrying accumulated salts and chemicals, and waste heat. The cumulative impact of dams, generating facilities, refineries, and other developments, each contributing incrementally to temperature increases of the river and estuary, can lead to biotic ecosystem changes.

A generating facility must import fuel to operate (12). Facilities fired by oil or coal require onsite fuel storage. The handling of these fuels may also lead to emissions, (6) such as hydrocarbon vapors (from fuel oils) or coal dust.

Waste products (14) may be directly discharged to the river or estuary (15), or stored at the site (16) for later disposal. The wastes may be treated and then discharged to the river (15), stored permanently or temporarily onsite, or exported to another location offsite (17). Waste disposal problems vary with the type of facility. Coal fired facilities produce the largest volume of material for disposal, primarily fly ash and scrubber sludge. This material is relatively nontoxic and usually trucked to a nearby fill area, which may ultimately be returned to productivity. The volume of nuclear power waste is not large but the toxicity is great. The issue of nuclear waste disposal is not fully resolved and is beyond the scope of this report.

4.7.6.3 Hazards related impacts. Spills (19) either from fuel or from waste storage at the site threaten aquatic ecosystems adjacent to and downstream from the site. These facilities normally have containment structures to minimize the spreading of an onsite spill.

In this model, spills are assumed to have exceeded onsite containment capabilities and to have entered the adjacent aquatic system. Such spills mainly result from human error during handling or transfer, or from failure of some part of the storage and handling system. Of primary concern are fuel oils, a coal spill not being particularly hazardous. The relatively low volumes and high level of containment precautions in the design, construction, and handling of nuclear wastes decrease their probability of entering the ecosystem; however, several spills have occurred at Hanford, with undetermined effects.

Another hazard is presented by the possibility of system failures (20), which could result from human error, as with the Three-Mile Island nuclear facility near Harrisburg, Pennsylvania, or from natural disasters (earthquakes, storms, volcanic eruptions), fire, explosion, sabotage, or war. Such hazards could also affect other energy facilities nearby, or even far upstream. A major dam failure on the Columbia River could destroy energy facilities sited in riparian habitats, contributing oil, nuclear fuel, and wastes to downstream and oceanic environments.

4.7.7 Ecosystem Model-Processing Facilities

Refineries and other processing facilities, such as coal gasification plants, produce impacts similar to thermoelectric generating facilities, so no new model is presented.

Operationally, a model for refineries would differ from the model for the thermoelectric generating facilities by the export of refined products (fuels or petrochemicals), rather than the export of electricity.

Hazard related impacts of a processing facility are modeled identically to those for thermoelectric facilities, but they differ in types of materials that could be released.

4.7.8 Ecosystem Model-LNG Facility

This model (Figure 4.18) shows a facility that includes a requirement for LNG storage and uses river water to warm the LNG in the gasification process. Construction impacts are minimal, a function mainly of the size of the facility. The hazards of LNG are great and include transportation through other habitats prior to reaching the facility.

4.7.8.1 Construction impacts. The area requirements for an LNG facility appear to be less than for a refinery or processing facility. Effectively, the facility consists of LNG storage tanks, gasification equipment (which exchange heat from river water to the LNG), and pipelines to export natural gas to the users.

Earthmoving (2) will result in disruption of habitat at the site and the release of dust to the air, probably affecting fish, wildlife, and vegetation in adjacent areas. Emissions from construction equipment can be quantified for a particular project, but are not considered a significant problem. Clearing (3) should be limited to the construciton roads and the actual sites of storage tanks and support buildings, and also the pipeline ROW. LNG facilities require additional land around them (buffer zones) which should not be developed due to the risk of explosion. Construction materials (4) will be imported to the site.

4.7.8.2 Operational impacts. The potential operational impacts of an LNG facility are relatively few. LNG vessels (7) must call at the facility to offload the raw material (LNG). The LNG is stored at the facility, and as a function of demand, is gasified and put into the pipeline for export as natural gas (6). The heat for gasification is derived from the river water (5) with a resulting small decrease in temperature of the receiving waters. This may actually be a benefit in view of the number of other energy developments that result in increases in water temperature (such as hydroelectric projects, fossil-fuel facilities, and nuclear power plants).

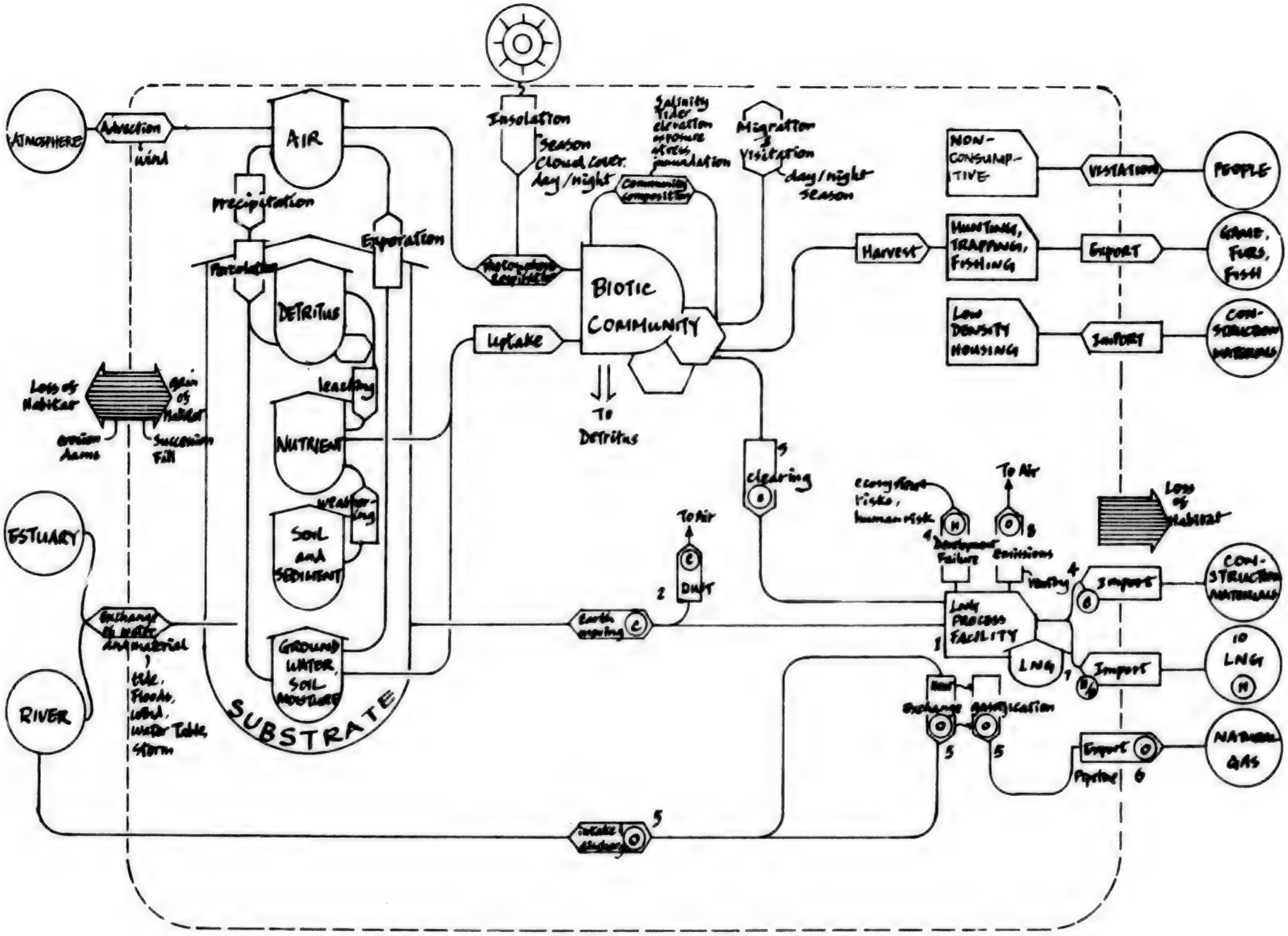

Figure 4.18. Riparian ecosystem model - LNG processing facility.

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4.7.8.3 Hazards related impacts. The principal hazard is the potential release and subsequent ignition of natural gas. This hazard is associated with vessels importing LNG (7, 10) and with the facility itself (7), and can lead to considerable damage to fish and wildlife (9).

4.7.9 Ecosystem Model-Transportation/Transshipment Facilities

Trucks, pipelines, railroads, and terminals are included in the transportation/transshipment category. Marine vessels are not included. The model is presented in Figure 4.19.

4.7.9.1 Construction related impacts. As with other developments, land requirements of the facility (1), earth moving and dust emissions (2), clearing (3), and importing of construction materials (4) are the principal construction related impacts. The land requirements, however, vary depending upon the facility considered. Trucks require roads, which may, for the most part, already be in place. Pipelines require ROW's, and considerable clearing may be necessary. Nevertheless, the land is not removed from biological productivity. Railroads already exist in the study area, but these may need improvements which could impact the riparian habitats along the river and estuary. Fuel storage requirements at the transshipment facility (terminal) pose the largest localized impact.

4.7.9.2 Operation related impacts. The operational impacts are mostly from hydrocarbon emissions from fuel storage or combustion emissions from transportation machinery. Heat is also released to the atmosphere (6) by machinery. The operation of a transshipment facility involves fuel storage and transportation to and from the facility (1,7). In the case of a coal terminal, leaching from coal storage (8) piles constitutes an operational impact. Maintenance of railroad tracks and roads usually involves continuous mechanical and chemical (herbicides) clearing (3). To some extent, similar clearing requirements will exist for pipeline ROW's as well.

4.7.9.3 Hazards related impacts. Spills (9) of toxic substances (generally fuels) may occur from the fuel storage areas at a transshipment facility, from the handling of the fuels at the facility, or from individual trucks, railroad tankers, or pipelines. These spills can reach the river and/or estuary if sufficient containment facilities are not present or functioning. In the case of a pipeline, groundwater may be contaminated from an undetected leak in an underground portion of the pipeline. Gross failure of a transportation facility can result in fires and explosions (10). Moving trains and trucks can frequently introduce the risk of fire or explosion to a populated area or an area of concern to fish and wildlife. Transshipment facilities containing larger quantities of the flammable or explosive materials present a risk as well. Containment facilities are built into the transshipment facilities, but not in the transportation facilities (except pipelines).

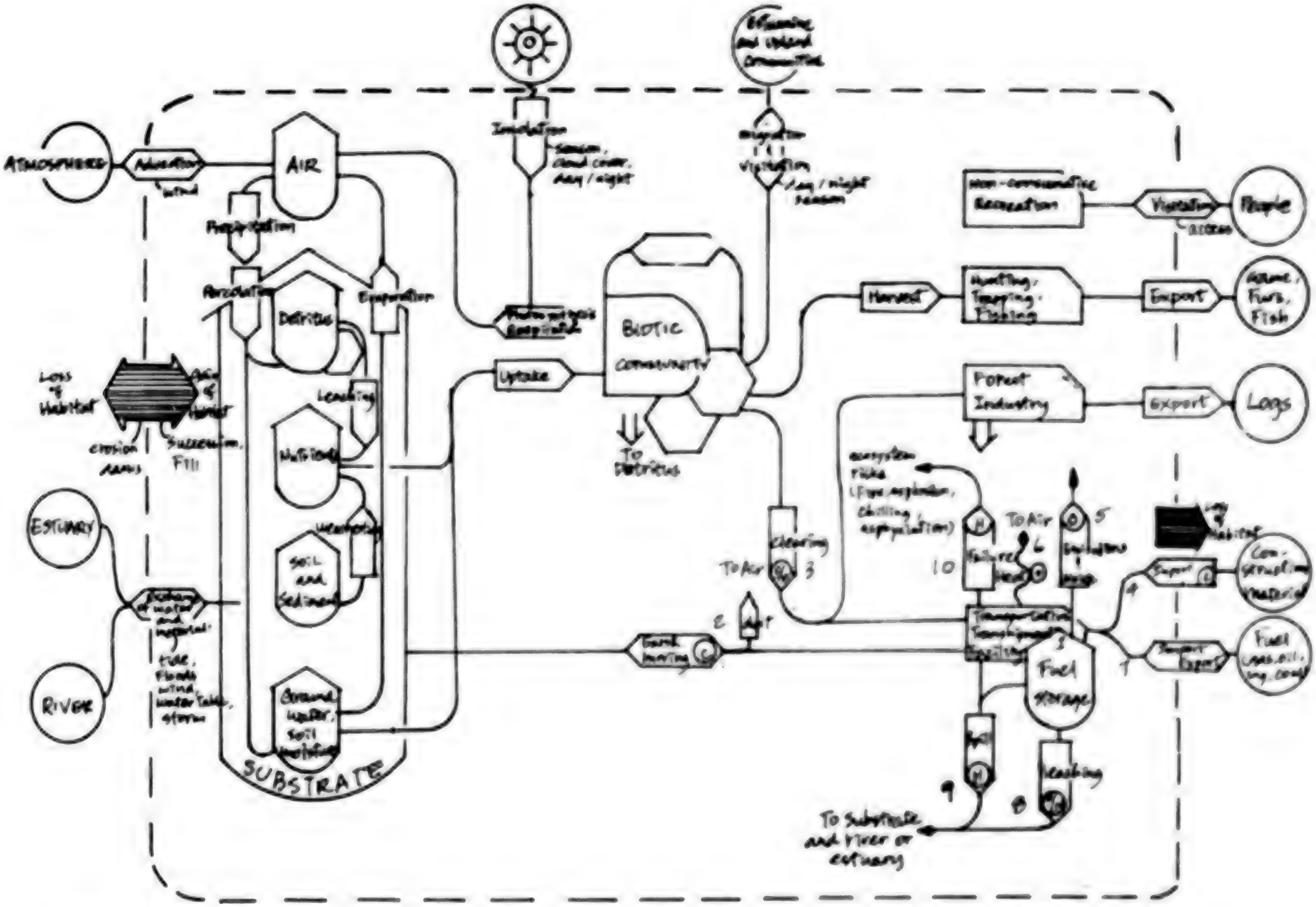

Figure 4.19. Riparian ecosystem model - transportation/transshipment facility (truck, pipeline, railroad and terminal).

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4.7.10 Ecosystem Model-Transmission Lines/Pipelines

The notable feature of this model (Figure 4.20) is the lack of operational impacts, the main impacts being construction related.

4.7.10.1 Construction related impacts. Construction related impacts of transmission lines and pipelines again result from earth moving (2), and clearing (3), related dust and combustion emissions (2, 5), and noise. Earth moving is greater for pipelines which are usually buried. In forested areas, cleared timber may be harvested (4). Construction materials (6) must be imported, and therefore access roads along the transmission lines ROW's are also needed. The clearing of ROW's does not entirely constitute a negative impact in forested upland communities.

Although transmission line ROW construction requires a considerable amount of land, impacts within riparian habitats bordering the river and estuary are not great. Most transmission lines will not be sited in or cross the Columbia River riparian zones. There are some points at which transmission lines cross the river, and these definitely will locally impact the riparian habitat. Pipeline crossings of rivers and streams have greater impact because of trenching requirements.

4.7.10.2 Operation related impacts. Operationally, transmission lines and support towers constitute a physical structure which can interfere with flying birds at night or during dense fog. Where transmission lines cross the Columbia River, it is necessary to have very large transmission towers to support the lines and keep them sufficiently elevated to allow ships to pass. Maintenance clearing of ROW's is a controversial operational impact when herbicides are used. The existence and maintenance of the access roads to the ROW create a habitat favorable to many forms of wildlife and also improves access to hunters to these forms of wildlife.

Pipeline crossing can result in unstable conditions along the shore causing erosion and wash out of the riparian community. In some cases the crossing is stabilized with riprap, permanently altering the shore. Pipeline crossings are also periodically washed out in the streambed proper and require retrenching. This causes additional construction related impacts along the riparian shore.

4.7.10.3 Hazards related impacts. The hazards associated with transmission lines are generally related to the potential of electric shock and sparks from downed lines. Shock potential is of low concern to riparian areas, but of higher concern in river, lake, and estuarine environments. The possibility of electric sparks from downed lines starting forest fires is of concern, especially during the dry season (late summer and fall). Failure of a transmission line or tower could result from severe storms, earthquakes, volcanic activity, or human activities such as flying or sabotage.

The hazards associated with pipelines arise from pipeline failure, leading to a release of the material being tranported. Oil could enter

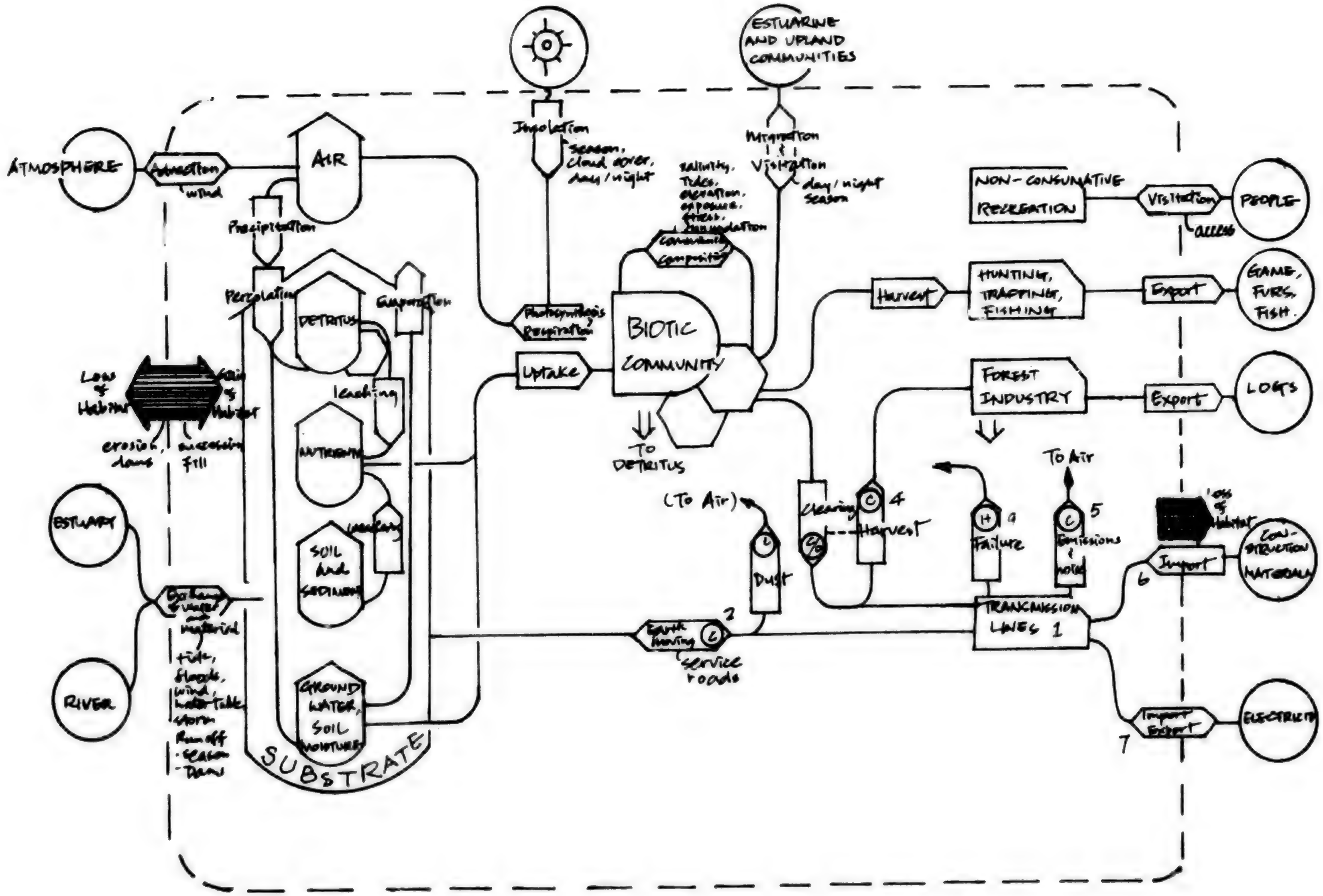

Figure 4.20. Riparian ecosystem model - transmission lines.

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groundwater aquifers or surface streams and rivers. Coal slurry could also contaminate aquatic systems. Natural gas and oil spills pose a fire hazard. Pipeline failures could occur from earthquakes, sabotage, or washouts at stream or river crossings.

4.7.11 Ecosystem Model-Riparian-Extraction Facilities

Construction related impacts from extraction facilities include earth moving (2) to build access roads to drilling pads, and clearing (4), with related dust emissions and noise increases (3). If exploration indicates an area has sufficient reserves of oil or gas, then development may occur. This will involve more road and pipeline construction, construction and operation of oil or gas rigs, and additional release of combustion emissions and noise (5). Development and exploration also involves the movement of drilling rigs and development materials in and out of the riparian habitats. The construction phase is not really similar to other energy developments. Wastes are generated during drilling (drilling muds, etc.) and may be removed from the area or left in place (7). Waste ponds are frequently maintained and can pose hazards to waterfowl and other wildlife.

For oil wells, pipelines, and storage facilities, suitable containment features can minimize the spread of spilled oil. Natural gas containment is not feasible, but escape to the atmosphere is not especially hazardous unless ignited. Figure 4.21 models the impacts of extraction facilities on the riparian zone.

The hazards of oil and gas extraction in riparian habitats are mostly related to spills, fires, or explosions (9, 11). Additionally, toxic substances can leach or spill during waste storage, and this leachate could prove hazardous (10). Storage facilities may contain crude oil extracted from the ground or fuel oil to power the drill or well. Natural gas and oil wells sometimes blow out, requiring containment and capping. The spills and fires that result from a blowout usually receive considerable publicity. The volumes spilled usually greatly exceed reasonable containment capabilities.

4.7.12 Ecosystem Model-OCS Support

OCS oil and gas exploration, development, and production require considerable mainland support ranging from construction of large drilling platforms to shuttling people, food, and materials back and forth. The impacts to the estuary are essentially all construction related. This involves two construction phases: 1) construction of the support facility and 2) construction at the facility of OCS equipment. Because the impacts are of a construction nature, this section is not further subdivided to cover operation impacts and hazards. Figure 4.22 models this type of development's impact on the riparian zone.

The OCS support facility requires land for storage of materials and for assembling very large structures such as drilling rigs and storage

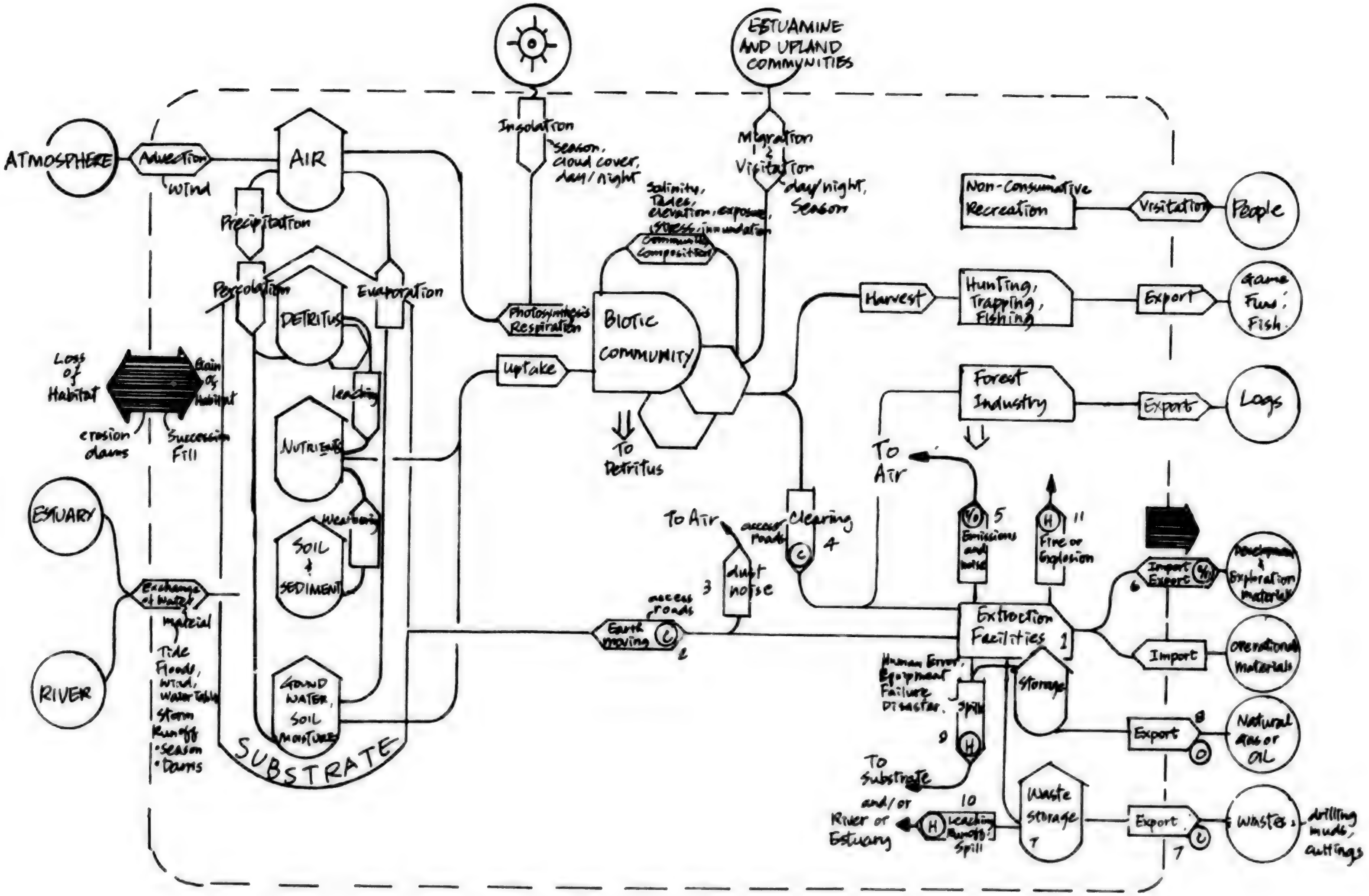

Figure 4.21. Riparian ecosystem model - extraction facilities.

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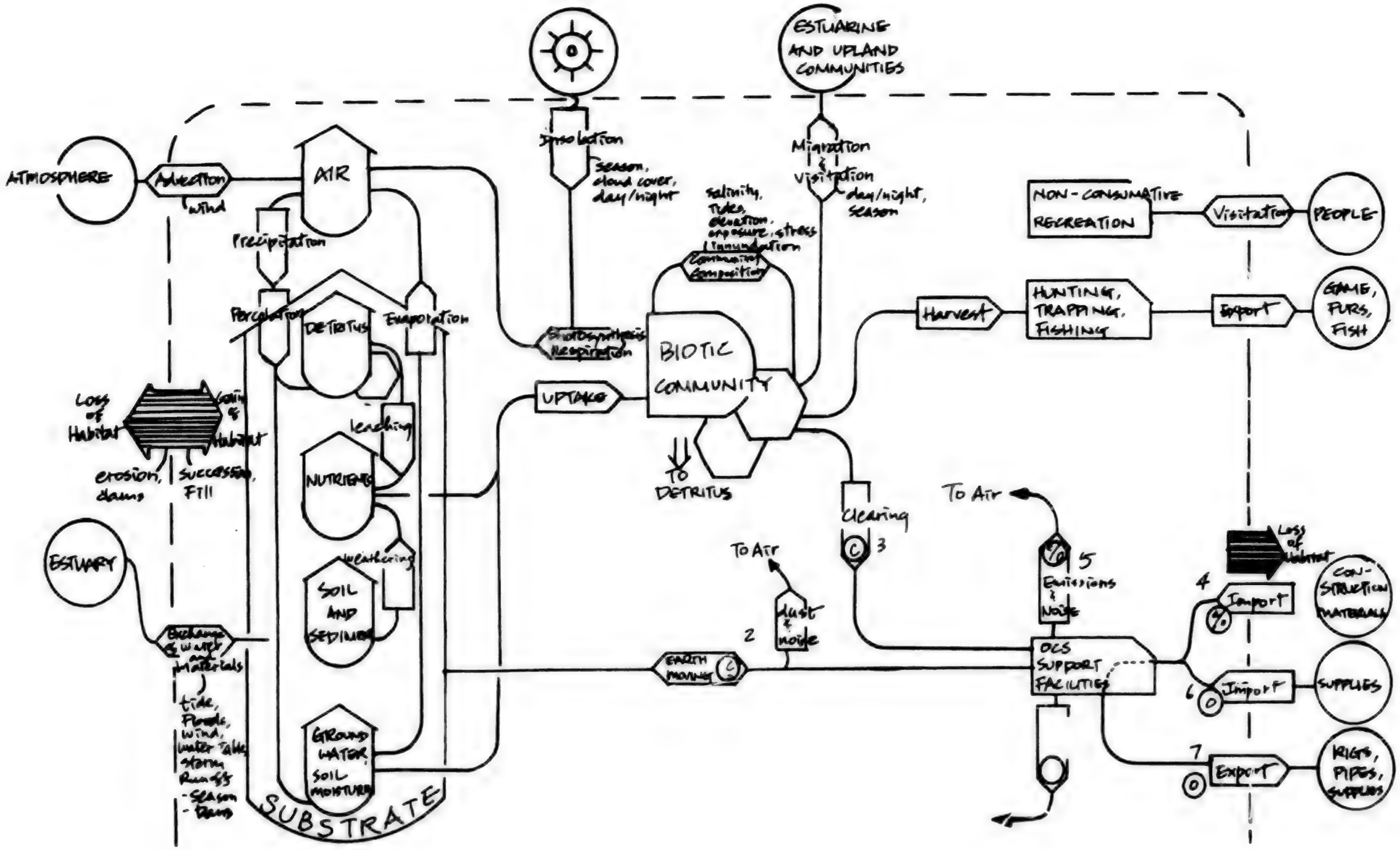

Figure 4.22. Riparian ecosystem model - OCS oil and gas exploration and development support.

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tanks. The initial construction of the facility itself requires earth moving and clearing (2, 3) with resulting dust, noise, and combustion emissions (2).

Once the support facility is producing OCS drilling rigs, the import of construction materials increases (4), and emissions and noise from construction continues (5). Supplies will be delivered to the facility (6), stored, and eventually shipped out (7) to offshore rigs. Rough sea conditions may sometimes preclude this shuttle of materials, requiring greater storage onshore and on the offshore rigs. Helicopters will also be used for transshipping lighter, less bulky items.

CHAPTER 5.0 SPECIES OF CONCERN

5.1 INTRODUCTION

The species of concern addressed in this report are Chinook salmon, coho salmon, steelhead trout, white sturgeon, American shad, dungeness crab, *Corophium salmonis*, waterfowl and shorebirds, great blue heron, western and glaucous-winged gulls, bald eagles, and Columbian white-tailed deer. These species were chosen primarily because they are of sport or commercial value (e.g., Chinook salmon), they are recognized as endangered species (e.g., bald eagle), or they are important prey (e.g., *Corophium*).

A brief overview of these species is given in Section 3.4 and Vol. 2 of the CPCR. This discussion gives some valuable background information on generic causes of endangerment and the significance of the commercial species to the region.

5.2 CHINOOK SALMON

5.2.1 Introduction and Description

Chinook salmon (*Oncorhynchus tsawytscha*), also called king, tyee, blackmouth, and jack salmon, is characterized by a heavily spotted tail and a black lower gumline. Spawning fish tend to be brown, olive green, and maroon with heavy black spotting. The Chinook is the largest Pacific salmon. Adult lengths range from 84 to 92 cm (33 to 36 inches), and weight is often 14 kg (30 lbs) or more. The Chinook is named after a Native American tribe once found along the Columbia River (Moyle 1976). The common name, tyee, is the Chinook word for large.

5.2.2 Resource Value and Estuary Usage

The Chinook salmon is an abundant and important commercial and sport fish of the lower Columbia River and Estuary. Races of Chinook salmon are identified according to whether they spawn in the spring, summer, or fall. At times abundance, migration, mortality, and limiting factors differ markedly among these three groups. Races of Chinook salmon differ according to the timing of spawning runs, age of spawning adults, and migrational behavior of juveniles (Moyle 1976). Differences in migratory characteristics are summarized in Table 5-1. Schematics of migrating and spawning populations are given in Figures 5.1 and 5.2.

Adult salmon are transient in the estuary, typically spending only a few days there en route to spawning areas throughout the Columbia River basin. The estuary, particularly adjoining bays and sloughs that provide

Table 5-1. Characteristics of the spring, summer, and fall races of Chinook salmon in the Columbia River.

Season	Age at maturity	Months adults may be found in estuary	Spawning areas	Age at which young may be found in estuary (May through August)	Dam passage required	Number of dams
Spring	4-6 yrs	Feb-March; peak in late March	Cowlitz R. area Willamette R. area	1 yr or more	None	0
	4-6 yrs	April-May	Snake R. (major) mid-water tributaries Bonneville to McNary dams	1 yr or more	Bonneville-Lower Granite	Up to 8
Summer	4-6 yrs	late May-June; peak in June	Salmon R. area	1 yr or more	Bonneville-Lower Granite	Up to 8
	4-6 yrs	May-June; peak in June	Columbia R. tributaries above Snake R.	6 months	Bonneville-Rocky Reach	Up to 8
Fall	3-5 yrs	July-Sept; peak in late August	Midriver hatcheries and tributaries; Bonneville-McNary dams	6 months	Bonneville-John Day	Up to 3
	3-5 yrs	late Aug-Sept; peak in early Sept	Hatcheries and tributaries below Bonneville Dam	6 months	None	0

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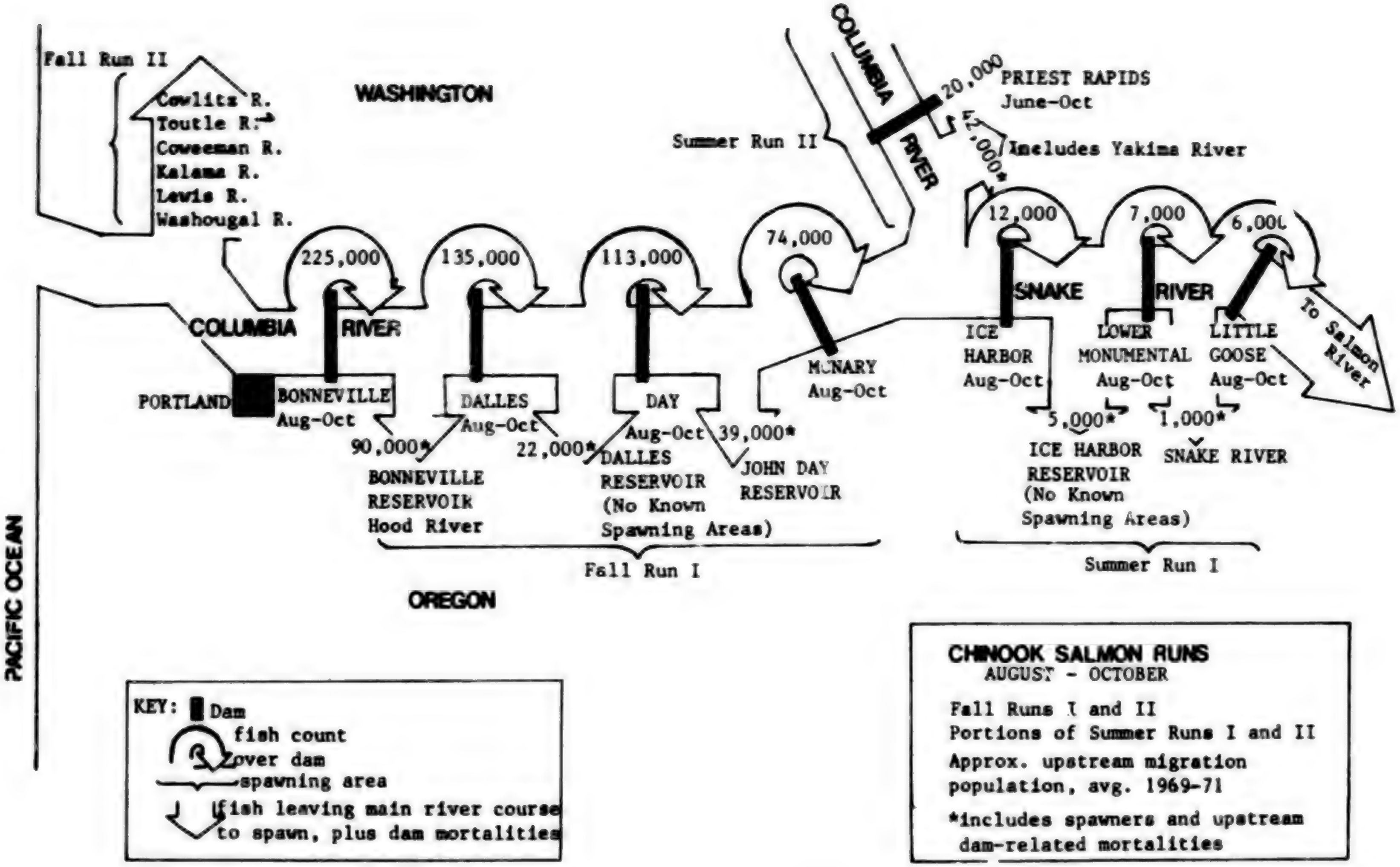

Figure 5.1. Estimated numbers of Chinook salmon in the summer and fall runs up the Columbia River and its tributaries; 3-year average, 1969-71.

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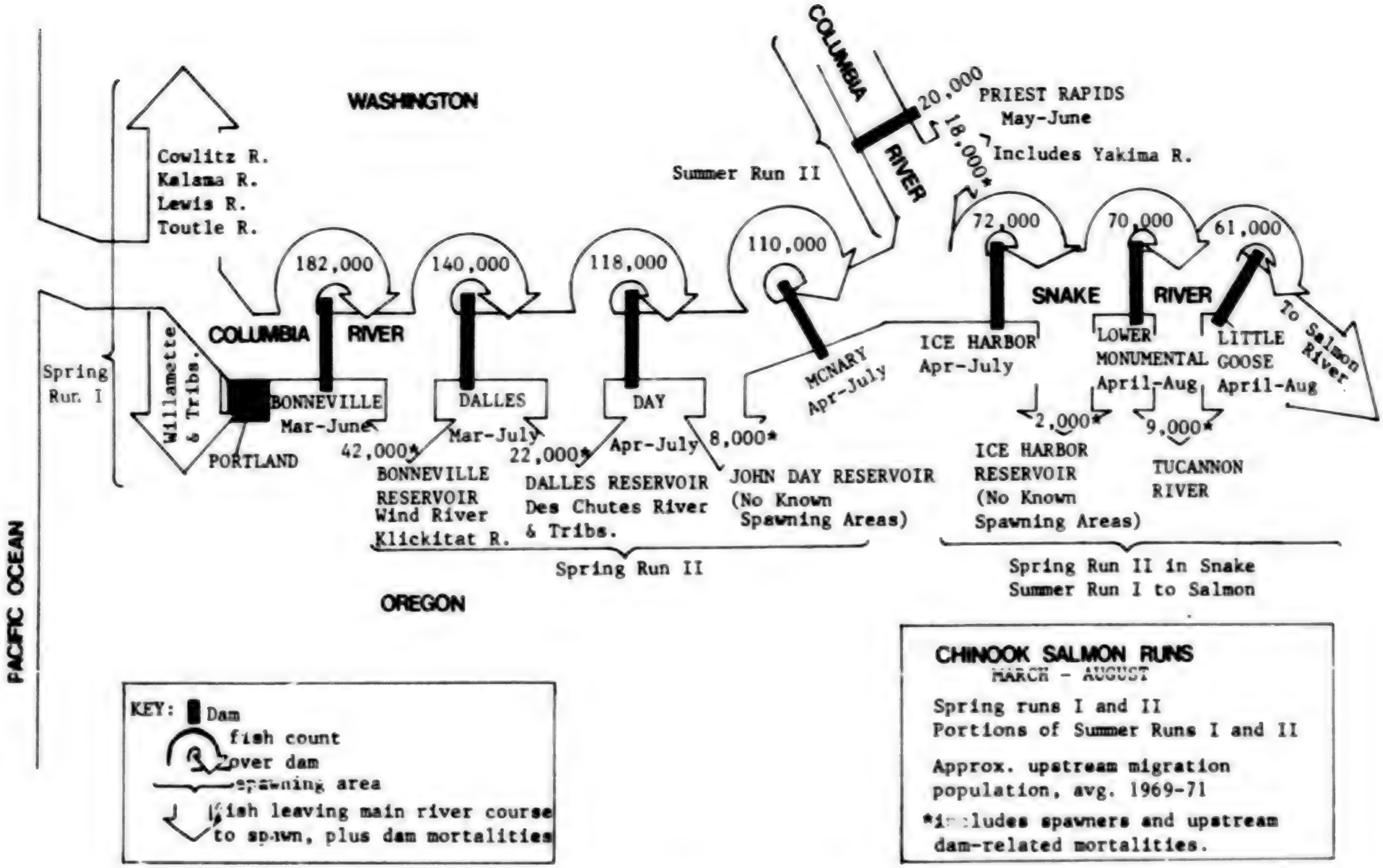

Figure 5.2. Estimated numbers of Chinook salmon in the spring runs up the Columbia River and its tributaries; 3-year average, 1969-71.

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protection and ample food resources, may be an important short-term habitat for some races of Chinook fingerlings.

Historically, fall Chinook juveniles enter the Columbia River Estuary from nursery sites and hatcheries in greatest numbers during July and August (Durkin et al. 1977). PNRC (1975) found the highest numbers of juvenile Chinook (7 to 8 million/month) passing the Bonneville Dam in a downstream direction during the months of May and June. Fall Chinook juveniles spend from December to June in fresh water and enter the estuary at six months of age. Spring Chinook remain in fresh water up to a year and enter the estuary as yearlings at about the same time of year as the fall juveniles. Summer Chinook from the mid-Columbia, which spawn from September to November, migrate downstream after their first spring and cannot be differentiated from fall Chinook by size.

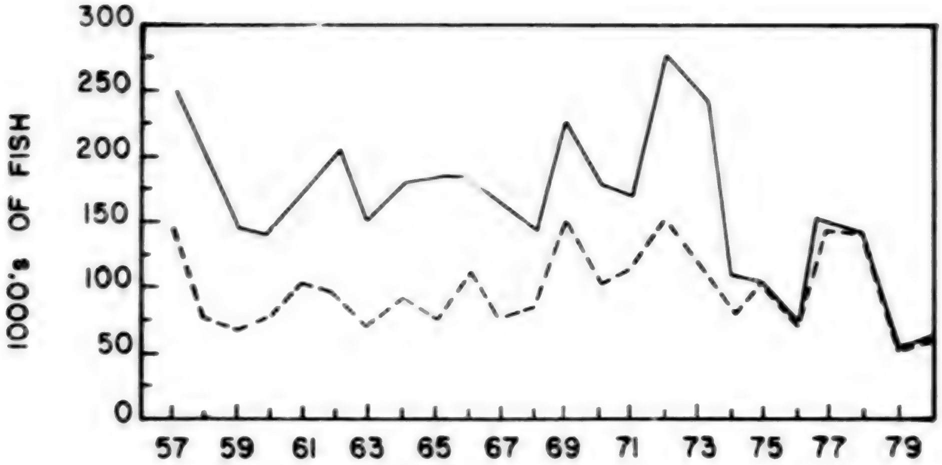
5.2.3 Population Status

The historical and current population estimates for the fall, spring, and summer races of Chinook salmon are presented in Figure 5.3. Generally, fall Chinook salmon make up about one-half of the total estimated annual runs, whereas spring and summer races make up only about one third and one fifth of these runs, respectively. The race of Chinook salmon above the Snake-Columbia river confluence may be threatened or even endangered (Columbia River Fisheries Council 1980).

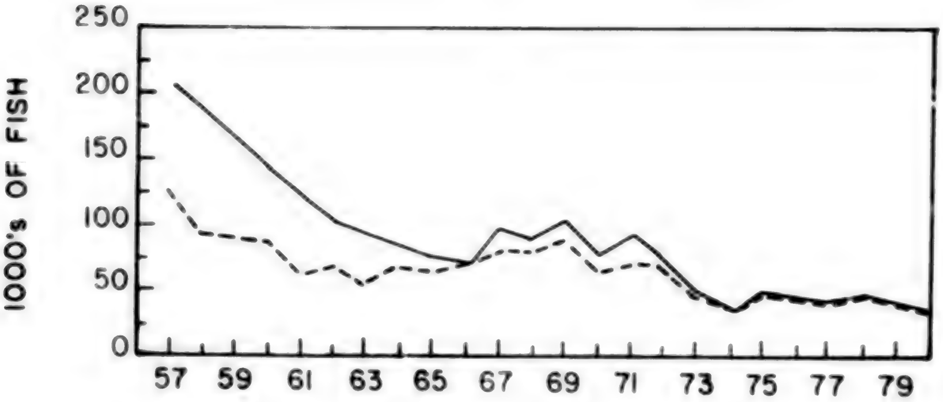
5.2.3.1 Spring Chinook salmon. Spring Chinook salmon enter the Columbia River in two major runs. The first run is composed of two nearly equal groups of fish destined for the Cowlitz and Willamette rivers, and takes place primarily between February and April, with peak numbers found during late March. The second run occurs between April and May and involves Chinook destined primarily for the Snake River, with a small segment headed for midriver tributaries between and above Bonneville and McNary dams.

As with all Chinook salmon in the Columbia River system, natural reproduction has declined seriously because of the obstruction of natural migration corridors, inundation of spawning habitat, degradation of natural habitat, and increased juvenile and adult mortalities due to dams, irrigation projects, and pollution. Steps being taken to minimize these losses among spring, summer, and fall runs are discussed by the NPPC 1982), Fish and Wildlife Committee (1979), and Columbia River Fisheries Council (1980). Losses in the lower reaches of the river have been compensated for largely by development of hatchery and natural production. In recent years, adult spring Chinook salmon produced in the lower river reaches have numbered approximately 200,000 annually.

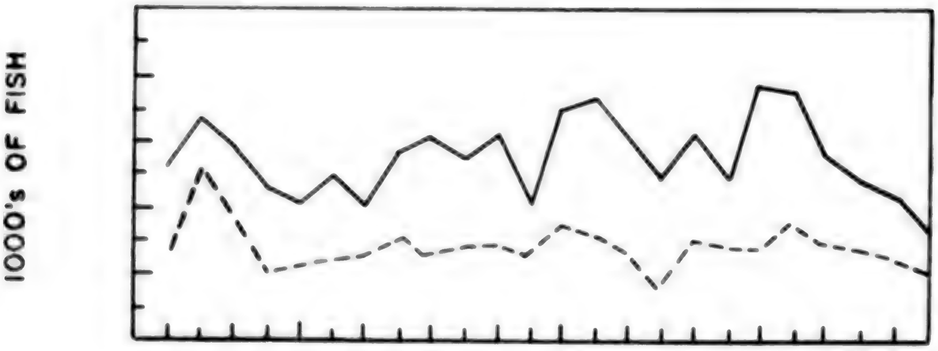
The prospects for upriver runs are not encouraging, but reestablishment of runs is possible if safe movement through and over dams is facilitated, if incidental harvesting through mixed stock fisheries (i.e., ocean sport and troll and main stem Columbia River gill net and sport fisheries which fish indiscriminately on a mixture of salmon originating from many different tributaries) is reduced, and if spawning and rearing habitat is maintained.



SPRING CHINOOK SALMON



SUMMER CHINOOK SALMON



FALL CHINOOK SALMON

Figure 5.3. Estimated numbers of Chinook salmon entering the Columbia River and escapement above Bonneville Dam, 1957-79 (Columbia River Fisheries Council 1980).

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Spring Chinook salmon formerly migrated almost the entire length of the Columbia River. Runs have declined as major upriver producing areas were cut off due to irrigation projects, splashdams, hydroelectric projects, inundation of spawning areas by impoundments, and destruction of spawning and rearing areas by siltation, debris, or pollution from sewage, farming, logging, and mining (Fulton 1968). Cut-off areas include most of the Walla Walla River system, a significant part of the Yakima and Okanogan rivers, and the entire area above Chief Joseph Dam. Currently, spring Chinook salmon produced in the upriver runs number approximately 100,000 annually (Columbia River Fisheries Council 1980).

5.2.3.2 Summer Chinook salmon. The summmer Chinook population inhabits two distinct spawning areas. One portion of the population migrates to the Snake River in Idaho, and the other spawns in tributaries of the Columbia above the Snake River. Adult summer Chinook travel through the estuary from late May through June, with peak occurrence in June (Chaney and Perry 1976).

Historically, the summer Chinook, which are the smallest Chinook of the Columbia River, averaging 6.4 kg (14 lbs) in weight (Fulton 1968), have been seriously overfished in the lower Columbia. Stocks were further depleted by construction of the Grand Coulee Dam which completely eliminated access to a large portion of their spawning grounds, and by the related mortalities of juveniles on the down-river passage. Fishing restrictions allowed a reestablishment of the stocks to a high in 1957, but populations have drastically dropped in the ensuing years. Mixed stock harvesting is also jeopardizing the run. Little research or effort has been completed on their artificial propagation, and with their continued high dam related mortalities, their near-future prospective does not look promising. Recent passage of the Northwest Power Bill, which requires protection of fisheries as important resources during the planning process of energy developments, will hopefully provide some impetus for recovery of these stocks.

5.2.3.3 Fall Chinook salmon. The fall Chinook run is divided into an early and late group. The early group is primarily destined for midriver hatcheries and tributaries between Bonneville and McNary dams and can be found in the estuary from late July to September, peaking in late August. The late group of the fall Chinook is found in the estuary in late August to late September, peaking in early September. These Chinook are destined for hatcheries and tributaries below Bonneville Dam.

As with other Chinook salmon, the fall Chinook has also been seriously affected by dams. Historically, there has been considerable fish production above Bonneville Dam. Their numbers, however, continue to decrease due to the failure of adult fish to pass over main stem dams to spawn. Rehabilitation of the upriver run has had low priority because of its low freshwater sport fishing value (Chaney and Perry 1976), but there has been increasing concern as to the status of these runs. Runs below and those which pass through fish ladders just above Bonneville Dam are doing well, with low dam related mortalities and high artificial propagation. Currently, these are the most important commercial and recreational runs through the estuary.

5.2.3.4 Juvenile and young Chinook salmon. Juveniles from the reaches of the river above Bonneville Dam are transient in the estuary, but those from the lower reaches are, at least in part, resident. The young fall Chinook moving out of the estuary tend to stay in shallow near-shore areas and avoid deep channels, while returning larger, yearling spring and summer Chinooks characteristically use channels. Yearlings are typically observed within three meters (10 feet) of the surface and travel in daylight hours. Transient summer and spring juveniles only spend approximately one week in the estuary prior to their departure. Fall Chinook juveniles are thought to reside about 15 days in the estuary.

Downstream migration patterns of Chinook juveniles through the estuary are complex and changing. Migration through the upper estuary has changed during the 1970's from a bimodal peak of May/June or July/August to a single peak in May/June (Dawley et al. 1979). Oddly, Sims (1979) indicated an opposite trend in the period 1965-1972 with the May/June peak declining and the August peak increasing. This shift is possibly a result in shifts of the relative mortalities from high flow gas supersaturation effects to low flow turbine blade effects.

Yearling Chinook travel through the estuary at the same time as the subyearlings, but use the deeper channels (Sims 1979). A small portion of the fall Chinook fry are nonmigratory, temporary parr residents which appear to use the estuary as a nursery. The estuarine presence of the nonsmolting juveniles has been clearly documented for other salmonids (Giger 1972). For cutthroat, above normal stream flows appears to stimulate inmigration of large numbers of parr (Giger 1972). The significance of this nursery population is not clearly documented and is under debate (Reimers 1973; Sims 1979; Durkin, National Marine Fisheries Service; pers. comm.).

The status of the populations of all three major runs of Chinook are controlled by factors outside the estuary. These factors are discussed in Section 5.2.6, Factors Affecting Distribution and Abundance. The estuary can, however, be a significant factor in the Chinook salmon natural history since all fish must pass through it twice in order for the reproduction cycle to be complete.

5.2.4 Life History

The average number of eggs per female is 4,000, but varies widely (2,000-14,000) and is proportional to body size (Moyle 1976). The majority of natural spawning occurs in upstream main channels of larger tributaries in depths over 25 cm (10 inches). Suitable water temperatures for spawning range from 5° to 14°C (41° to 58°F); Chinook require dissolved oxygen concentrations of at least 8 ppm. Water velocity required by these fish ranges from 30 to 100 cm/sec (1.0 to 3.0 ft/sec) over coarse gravel 5 to 15 cm (2 to 6 inches) in diameter (Thompson et al. 1972). Since the mid 1970's, hatchery production has made up approximately one-half of the total population (Coon 1979).

Adult Chinook are larger than other Pacific salmon mainly because of the typical two to five year period they spend at sea. The average size attained by adults is typically 97 cm (38 inches) in length with a weight of 14 to 18 kg (30 to 40 lbs) (Scott and Crossman 1973). Individuals over 45 kg (100 lbs) and over 130 cm (50 inches) have been caught, but these are typically from more northerly waters (Scott and Crossman 1973). The summer Chinook run, virtually eliminated by Grand Coulee Dam, was characterized by particularly large fish. Chinook usually weigh 1 to 2 kg (3 to 5 lbs) after one year and 9 kg (20 lbs) more after three years in the ocean. Average spawning adults attain a length of 75 to 80 cm (30-31 inches) and a weight of 9 to 10 kg (20-22 lbs) (Moyle 1976). Chinook salmon attain sexual maturity in three to five years, but some males, referred to as jacks, spawn in two years. Within the Columbia River system sexual maturity at four to five years is more typical.

5.2.5 Food Habits

Examination of stomach contents of juvenile fall Chinook from Young's Bay showed that the amphipod *Corophium salmonis* was the major food consumed in May through August. It comprised about 75 percent of the recognizable prey in stomach contents. Juvenile Chinook salmon were also observed to consume significant amounts of larval shiner perch. A shift in food preference in September was marked by feeding primarily on insects, isopods, and seeds. Other food organisms noted were the amphipod *Anisogammarus confervicolus*, *Diptera* flies, and the mysid, *Neomysis mercedis*.

5.2.6 Factors Affecting Distribution and Abundance

5.2.6.1 Natural factors. Survival for smolt under natural conditions is estimated at 10 percent, but may vary widely depending on environmental conditions, predation, and dam related mortalities. Survival from egg to smolt in well managed hatcheries is approximately 80 to 90 percent. Predation by piscivorous fishes, birds, and mammals, as well as disease, are important mortality factors. Natural mortality may be caused by excessively high temperatures, pH changes, low flows, reduction in dissolved oxygen, and siltation.

Oceanic losses include natural predation, harvesting, and disease. The total return to the spawning grounds is approximately one percent, but varies widely. Natural replacement of population losses requires a return to the spawning areas of 0.1 percent of the population.

Streams have a limited amount of spawning area and are only able to accept a finite number of spawning pairs. Excessive numbers of spawners usually do not increase the size of the hatch. In recent years, the abundance of spawners in spawning grounds has been very low, and the spawning areas are underutilized (Fish and Wildlife Committee 1979).

Other than the scarcity of spawners and spawning beds, water quality, waterflow, passage, and suitable gravel are the principal limiting factors to natural reproduction (see Section 5.2.4). Juveniles require a minimum depth of 3 to 6 cm (0.1 to 0.2 ft) for intrastream movement during their rearing period (Thompson et al. 1972). The minimum depth for successful passage of Chinook salmon on their spawning runs is considered to be 24 cm (0.8 ft) of water (Thompson et al. 1972). Seasonal low flows in July through October can reduce or block movement.

5.2.6.2 Human factors. Generally, some of the more obvious factors responsible for the destruction of spawning and rearing areas are: (1) reduction of stream flow and blockage by irrigation projects and splashdams; (2) blockage by hydroelectric projects; (3) inundation of spawning areas by impoundments, and (4) destruction of spawning and rearing areas by siltation, debris, or pollution from sewage, farming, logging, and mining. Poor logging practices in the past have reduced the reproductive carrying capacity of the area through the destruction of spawning areas, scouring of streambeds, and blockage of stream access (Thompson and Snow 1974; USDA 1976; Poon and Garcia 1982). Removal of cover from the watershed causes erosion, and the resulting siltation causes excessive turbidity in the waterways. Future public and private logging may continue to decrease reproductive success because of the resulting unusually high sedimentation, low stream flows, and excessively high water temperatures.

High mortalties of juvenile salmon at main stem Columbia and Lower Snake rivers hydroelectric projects are the main cause of the current precarious condition of the upriver run. A description of existing fish passage facilities in operation at main stem dams is given in Chapter 8. Tributary storage has virtually eliminated the dramatic peak spring runoff which once transported juveniles quickly from spawning and recurring areas to the Pacific Ocean.

At high and low flows, dam related mortalities to juveniles are estimated at 5 and 45 percent, respectively, for seaward migrants (Columbia River Fisheries Council 1980). During high river flows, juvenile migrants pass through reservoirs and spillways, while during low flow conditions, virtually all water is passed through turbines.

During high flows, turbine mortality is reduced, but mortality due to gas bubble disease, which is caused by supersaturation of nitrogen in the water, is increased. Data developed by the National Marine Fisheries Service indicate that 70 percent of young Chinook in the Snake River which migrated in 1970, and 50 percent of those which migrated in 1971, were lost primarily because of gas bubble disease prior to reaching Ice Harbor near the mouth of the Snake River (Columbia River Fisheries Council 1980). This percentage is three times the estimate made prior to the construction of Lower Monumental and Little Goose dams. Data developed at the Dalles Dam indicate migration losses as high as 95 percent or a dozen times greater than the mortality rates with similar flows prior to the installation of Little Goose, Lower Monumental, and John Day dams (Columbia River Fisheries Council 1980). An USEPA study (1971) stated that of downstream Chinook migrants arriving at Ice Harbor Dam on the Snake River, 25 to 45 percent exhibited visible gas bubble disease. Supersaturation related mortality has been nearly eliminated for the main stem of the Columbia River in recent years.

From a number of other studies cited by USEPA (1971), it appears that the time of downstream migration of juvenile salmonids has been delayed because of river impoundment by dams. Downstream juvenile migrants have historically migrated during periods of high flow and moderate temperatures; delays in this pattern bring them into peak summer temperatures and curtailed flow conditions, which increase stress and appear to reduce survival rate.

Mortalities are also inflicted on adults at dams and range from 2 to 20 percent, depending on the dam, ladder facilities, and flows. High flows improve successful migration and decrease mortalities.

Sims (1979) demonstrated over a three year study period that transporting juvenile Chinook salmon from hatcheries located on the Bonneville Reservoir to areas just below the dam increased survival by 51 percent in 1968 and by 30 percent in 1969.

Mortalities of migrant Chinook salmon due to gas bubble disease have been reduced by dam spillway modifications, such as flip-lips, flip-lips with barricades, and concrete aprons. Ironically, mortalities have also been decreased by reduced spills largely due to the expansion of main stem powerhouses and the addition of a number of large storage projects. Currently and in the foreseeable future, mortality problems are largely associated with low flows.

Another impact on salmonids due to human related activities results from the alteration of the temperature regime of the river and estuary (USEPA 1971; Craddock 1976). Man caused temperature increases have been occurring since the 1950's with the principal effect of shifting water temperature maximums to later in the year. For example, releases of warm water from the Cottage Grove Dam prevent use of downstream areas by spring Chinook. Total higher thermal conditions are thought to adversely affect juveniles and adults and cause thermal blocks to migration.

Certain tributaries of the Columbia River System have ceased to be viable spawning areas for Chinook salmon. The Santiam and Willamette (Coast Fork) rivers and Potlatch Creek are examples of waterways made unusable by high temperatures. Temperature effects on Chinook and other salmonids have been thoroughly reviewed by the USEPA (1971). They summarize the following for adult fish:

> Warm water endemic Columbia River infections and diseases are less likely to cause salmon mortality at temperatures below 15.5°C (60°F).
>
> Under controlled laboratory conditions, predators were shown to selectively prey upon fish whose behavior had been modified by temperature stress.
>
> High temperatures can increase potential nitrogen supersaturation problems.
>
> There is a tendency for adult salmon and steelhead trout to cease upstream migration through waters with temperatures of 21°C (70°F) or above.
>
> Water temperatures above 21°C (70°F) are considered directly lethal to fish and are more serious due to their synergistic effect (e.g., gas bubble disease).

For eggs and juveniles the following is summarized:

> Egg incubation period is critically sensitive to water temperatures, and eggs will hatch in a range of 5° to 16°C (41° to 61°F).
>
> Diurnal temperature fluctuations in the range of 5.5° to 18.3°C (42° to 65°F) is of significant benefit to growth and survival of eggs and fry.
>
> Growth of juveniles is optimum at 5° to 17°C (41° to 63°F); temperatures below or above may be deleterious, depending on other factors present, such as oxygen concentrations.
>
> Timing of juvenile downriver runs may be delayed due to main stem dams posing potential temperature stress.
>
> Temperatures above 20°C (68°F) are considered adverse to juvenile salmonids, and temperature increases between 17° to 20°C (63° to 68°F) will increase the susceptibility of these fish to infection and other environmental stresses.

The fractionalized management responsibilities incur problems associated with the overexploitation of a common resource by competing users. The inability to selectively fish for healthy stock in mixed stock fishery without causing potentially serious effects on depleted stocks is an expression of this problem (Columbia River Fisheries Council 1980). Mixed stock fishery methods involve capture of a mixture of salmon originating from many areas. This makes it very difficult to protect weak stock (such as summer Chinook) without sacrificing harvest of healthy stock.

The Oregon Fish Commission estimates that five Chinook salmon are caught by commercial and sport fishermen for each salmon returning to spawn. An estimated 71 percent of this catch is taken commercially, and 29 percent is taken by sport fishermen (USDA 1976). The Columbia River Fisheries Council (1980) roughly estimates one-half of the spring and summer Chinook and two-thirds of the fall Chinook are caught at sea, although these data are not reliable. Only a small portion of the salmon are harvested within the estuary.

Propagation techniques in hatcheries have come under criticism in recent years with regard to their selection process and resultant decrease in the genetic variability of stocks. Franklin (1980) eloquently details evolutionary changes in small populations which include genetic drift, inbreeding depression (due to fixing of deleterious genes), random changes in phenotype, and decrease in genetic variance. The potential effect of hatchery production and mixed stock harvesting is the reduction of genetic variability of Columbia River Chinook salmon populations, making them vulnerable to environmental modifications or catastrophies.

5.3 COHO SALMON

5.3.1 Introduction and Description

The coho salmon (Oncorhynchus kisutch) is also known as silver, silverside, and hooknose salmon. In salt water it is identified by the olive green color on the back, light spotting on the upper half of the caudal fin (and none or few on the lower half), and a white lower gumline where teeth project from the jaw. Spawning adults are reddish-black on the head and back, shading to red on the side. Spawning males characteristically have a bright red lateral stripe. The coho is one of the most important sport and commercial fishes in the Pacific Northwest and the Columbia River Basin. Cohos typically reach maturity at three years and weigh 2.7 to 5.5 kg (6 to 12 lbs) or more.

5.3.2 Resource Value and Estuary Usage

Economically, the coho salmon is the second most important fish in the Columbia River area. It is highly sought after by commercial trawlers and sports fishermen near the river's mouth and all along the coast. In response to increased coho production in the 1960's as a result of improved hatchery techniques and production, gill nets areas which had been closed for over 30 years were opened in the estuary in Youngs Bay.

Adult coho may spend as long as one month in the estuary prior to ascending the rivers and tributaries in order to spawn. Juvenile coho, which are about a year old at the time they reach the estuary, spend very little time there (1-4 days) (Sims 1970). Nearly all the factors which seriously affect key coho salmon population parameters (i.e. mortality, birth rate, limiting factors) are geographically external to the estuary. Consequently, the estuary should be viewed as a conduit. However, significant alteration of environmental parameters (particularly water quality) within the estuary has importance to the coho, since the coho must pass through the estuary twice in order to complete its reproductive cycle.

5.3.3 Population Status

Coho salmon are abundant and are intensively managed throughout the river-estuarine system. Populations declined in the 1950's, but increased substantially in the 1960's, as documented in Table 5-2. There has been a recent and poorly understood stock reduction in recent years. Additional increases in hatchery smolt production and plantings in the Columbia River since 1967 have not resulted in significantly increased adult production (Gunsolus 1978). Currently, about two thirds of production (harvest) is from hatchery plantings (Gunsolus 1978). Table 5-2 presents recent production data for the Oregon Production Index Area (OPI) which includes Oregon coastal and Columbia River stocks. Population status for the 1980's are predicted to be below the 1960 and 1970 levels (Oregon Department of Fish and Wildlife 1981; Pacific Fisheries Management Council 1980).

Adult coho typically migrate through the estuary in deeper channels from August through November, with a peak occurrence in September (Chaney

Table 5-2. Oregon production of adult coho (in thousands of fish), 1961-80.

Adult Production Year	Adult Production Areas[a] Ocean Troll	Sport	Columbia River	Oregon Coast	Total
1961	525	174	69	24	792
1962	449	273	110	31	863
1963	757	343	107	29	1,236
1964	947	361	359	53	1,720
1965	1,195	509	385	46	2,135
1966	1,270	404	582	41	2,297
1967	1,652	641	592	53	2,948
1968	1,372	479	331	40	2,222
1969	907	426	309	42	1,684
1970	1,374	475	868	51	2,768
1971	2,403	682	522	63	3,670
1972	1,208	534	266	21	2,029
1973	1,251	424	284	31	1,990
1974	1,987	633	453	40	3,113
1975	1,016	423	279	7	1,725
1976	2,779	872	269	38	3,958
1977[b]	650	310	85	15	1,060
1978[b]	989	532	296	6	1,822
1979[b]	993	314	250	22[c]	1,579
1980	--	--	--	--	<1,000[d]

Source: Pacific Fisheries Management Council 1980, Gunsolus 1978.

[a] Components are troll: California, Oregon, Washington[e]
sport: California, Oregon, Washington[e]
Columbia: gill-net catch, hatchery, and dam counts
Oregon Coast: Hatchery and wild spawners

[b] Preliminary results

[c] Does not include returns from off-station hatchery releases

[d] Projected based on 1979 jack counts

[e] Washington port at Columbia River mouth

and Perry 1976). Typically, the majority of adult coho are thought to remain in the upwelling waters off the coast from Oregon to central Washington, and do not travel as far away from the mouth of the Columbia River as Chinook salmon do (Oregon Department of Fish and Wildlife 1982). Juveniles characteristically spend a year in freshwater streams. Most adult coho are destined for spawning areas below Bonneville Dam, and those that do go aver the dam are all from hatchery stocks.

Special measures have been taken in recent years to protect this depressed stock (Pacific Fisheries Management Council 1980).

5.3.4 Life History

The majority of natural spawning occurs in lower tributaries of the Columbia River, specially in the Lewis and Clark, Youngs, Klaskanine, Elochoman, Grays, and Chinook rivers, and the Bear, Big, and Gnat creeks. Survival to smolts under natural conditions is established at 10 percent, but varies widely depending on environmental conditions. Survival to smolts in well managed hatcheries is 80 to 90 percent. The principal coho spawning areas are hatcheries, including the Klaskanine River, Big Creek, Gnat Creek, Elochoman River, Grays River, and Chinook River hatcheries.

Spawning requirements include clean uncompacted gravel 0.5 to 13 cm (0.2 to 5 inches) in diameter (the extremes being less favorable) and 15 to 30 cm (6 to 12 inches) in depth. Dissolved oxygen required is 7 ppm or higher, with a minimum spawning depth of 18 cm (0.6 ft) and a water velocity of 0.3 to 1.0 m/sec (1 to 3 ft/sec) at 12 cm (0.4 ft) from the bottom (Thompson et al. 1972).

Coho spend their first year in streams where they grow to about 13 cm (5 inches) in length and a weight of about 20 grams (0.7 oz). Growth in the marine environment is rapid. Weights of 4 to 5 kg (8 to 10 lbs) are reached in two years (Williams et al. 1975). Gunsolus (1978) reports that the growth of adult coho is related to the presence of good upwelling conditions. They typically reach sexual maturity in three to five years, but male jacks often attempt to spawn after one year at sea, when they are two years old.

5.3.5 Food Habits

Adult coho feed on small fishes in the upper 30 m (100 ft) of offshore waters. During their first year in the ocean, they feed heavily on crab megalops larvae. Although little feeding data exists, adult dependence on estuary food items is not considered to be significant. For a summary of food habits in oceanic and riverine habitats, see Hart (1973), Scott and Crossman (1973), and Moyle (1976).

Juveniles are thought to spend only a few days in the estuary, typically around the first two weeks of May. Consequently, their dependence on estuarine prey is limited. Analysis of the stomach contents of juvenile coho captured in the estuary revealed almost exclusive consumption of the amphipod Corophium salmonis (Durkin et al. 1977).

5.3.6 Factors Affecting Distribution and Abundance

5.3.6.1 Natural factors. Natural populations of coho salmon depend on small coastal streams with sufficient water quality and access. Due to increased hatchery production and harvest and a reduction in spawning stocks, it now appears that at least some natural spawning areas may be underutilized.

Gunsolus (1978) reports that the ocean food supply associated with upwelling conditions may limit growth and survival. Durkin (pers. comm.) notes that years of low coho salmon productivity are not necessarily low for Chinook productivity, although they are dependent on similar oceanic upwellings and associated food availability.

Factors for survival of hatchery produced fish differ markedly from those of fish produced naturally. Due to high egg to smolt survival rates, hatchery reared fish are able to withstand high fishing mortality rates (8:1, eight fish caught for every one escaping to return to spawning grounds) while naturally produced fish cannot withstand more than a 3:1 harvest-to-escapement ratio (Gunsolus 1978). Since hatchery produced fish make up two-thirds of the harvestable population, the current mixed stock harvesting efforts are believed to result in overexploitation of the natural spawners.

Low summer flows appear to be a significant limiting factor to natural reproduction for coho salmon in the Columbia River system (Thompson et al. 1972). Poon and Garcia (1982) and USDA (1976) have documented other limiting factors including elevated water temperatures and siltation increases due to extensive logging and poor road construction and development practices. These may have also affected natural reproduction, by destroying habitats and increasing mortalities. Generally, the effects of logging on salmonids are highly variable and must be analyzed on a site-specific basis (Gibbons and Salo 1973).

Predation by piscivorous fish and birds on smolt and fry can be an important contributor to coho mortality rates. This rate may also be increased by excessively high water temperatures and siltation. These combined factors contribute to the 98.5 percent estimated mortality from egg to smolt stage for natural spawners (Gunsolus 1978). Survival of ocean going hatchery smolt is estimated at seven times greater (14.1 percent mortality).

Peak coho populations are frequently followed by very poor years, indicating to some that interspecific predation might be a factor, particularly in poor upwelling years (Gunsolus 1978).

The discussion of factors affecting distribution and abundance of Chinook salmon largely applies to coho salmon.

5.3.6.2 Man-made factors. Coho are directly affected through sport and commercial harvesting. Indirectly, land use practices which alter limiting factors (such as water stream flow, water temperatures, sediment, available gravel, passage) affect the ability of an area to support viable populations of coho. The abundance of coho salmon in the Columbia River system is thought to have been reduced as a result of poor logging practices (Burns 1972; Thompson et al. 1972; USDA 1976), changes in land use which may cause excessive siltation and rapid runoff, and to a lesser degree the effects of dams (Fulton 1970). Since coho typically spawn in small coastal streams and in streams of the lower reaches of the estuary, their stocks have not been as seriously affected by dams as have Chinook salmon and steelhead trout. Inundation of spawning areas and the disruption of salmon migrations by dams has been offset in many places by hatchery production. However, this may result in a long-term loss of the natural spawning population.

A possible consequence of extensive hatchery programs is the potential deleterious effect of reduced genetic heterogeneity. Franklin (1980) eloquently details potentially deleterious evolutionary changes in small populations which could be applicable to all migratory species having a significant degree of hatchery production. The selective hatchery breeding processes often result in a small breeding population with consequent potentially deleterious effects on the long-range viability of the species.

Another potential problem incurred as a result of the hatchery programs relates to the differential harvest pressure of mixed stock harvesting. Commercial and sport fisheries are strictly regulated, but necessary returns to spawning streams are not assured since open sea fisheries are indiscriminate in terms of specific stocks caught. Consequently, it is possible that depleted natural genetic stocks may be overharvested.

The Oregon Fish Commission estimates three coho are caught by commercial and sport fishermen for each fish that returns to spawn. More recently, the ratio has been increased to 5:1 because more intense troll efforts are in effect. Approximately 71 percent of the catch is taken commercially, and 29 percent is taken by sports fishermen (USDA 1976), but these figures vary.

The pattern of coho mortality has changed in recent years. Commercial and sport fisheries are taking a larger proportion of fish but of smaller average size per fish.

Since coho runs are principally destined to lower river tributaries, their spawning runs would have to pass fewer dams than most other anadromous salmonid populations, such as spring Chinook salmon. There is an annual upriver coho salmon run of about 300,000 fish which does have to go over and through the Bonneville dam. Upriver migration of spawners occurs in September, when stream flow is lowest, and results in some mortalities.

5.4 STEELHEAD TROUT

5.4.1 Introduction and Description

The steelhead trout (*Salmo gairdneri gairdneri*) is an anadromous rainbow trout; it grows to a large size and matures in the ocean. It is silvery, with a wide incandescent rainbow stripe running along the lateral line from the cheek to the base of the tail. Small black spots mostly above the lateral line are characteristic. Spawning males are characterized by a long, hooked snout, while females have a short, blunt head.

The Columbia River supports winter and summer steelhead runs. Typically, summer run steelhead are destined for spawning areas above the Bonneville Dam, and the winter runs are destined for tributaries below the dam.

5.4.2 Resource Value and Estuary Usage

Steelhead trout are difficult to catch, prized sport fishes. Until 1974 when commercial harvesting was curtailed, steelhead was a historically important commercial species.

The estuary is an ecological conduit for this species. Summer steelhead enter the estuary from April through October with maximum abundance in July to early September (Chaney and Perry 1976). Winter run steelhead begin entering the river in November and run until March. Steelhead generally move through the estuary during high river flow. Young steelhead migrate seaward between March and June.

In the estuary, adults generally travel in main channels, but occasionally along the shore in shallow water. Juveniles migrate through the estuary in the spring, with maximum numbers of fish occurring in May (Sims 1969, 1970; Dawley et al. 1979). Travel time in the estuary appears to be short and is estimated at two days or less (Dawley et al. 1979). They typically travel near the surface in main channels (Johnsen and Sims 1973).

5.4.3 Population Status

Nearly all mortality, reproduction, and feeding for adults and juvenile steelhead occur outside the Columbia River Estuary. Population status is largely dependent on factors outside the estuary. However, since all steelhead must pass through the estuary twice, maintenance of natural conditions is an important factor in the success of steelhead populations.

Populations of steelhead over recent years for the runs throughout the Columbia River Estuary are provided in Tables 5-3 and 5-4 and Figure 5.4.

Winter run steelhead trout populations are high and relatively stable due to sufficient natural reproduction and survival, large hatchery releases in the lower Columbia River, and the absence of dam related

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Table 5-3. Estimated numbers (in thousands) of upriver summer steelhead entering the Columbia River, escapement, and percentage of the run landed, 1957-78.

Year	Upriver count	Bonneville count	Escapement count	Percent escapement	Total landings	Columbia River sport landing	Percentage of upriver count landed
1957	229.6	138.0	137.8	93	91.8		40
1958	211.2	130.7	126.8	97	84.6		40
1959	231.6	128.6	127.8	99	103.8		45
1960	199.8	113.1	111.8	98	88.0		44
1961	227.9	138.7	137.2	98	90.7		40
1962	251.7	163.0	162.5	99	89.2		35
1963	228.8	128.4	119.9	93	108.9		48
1964	178.6	116.2	109.5	94	50.4	18.7	28
1965	227.3	165.6	152.4	92	54.8	20.1	24
1966	209.2	142.9	139.8	97	39.4	30.0	19
1967	167.3	120.0	104.2	86	41.7	21.4	25
1968	161.6	106.5	97.1	91	36.5	28.0	23
1969	171.9	139.3	125.2	89	35.4	11.3	20
1970	138.7	113.2	100.0	88	29.3	9.4	21
1971	224.1	193.1	167.4	86	46.3	10.8	20
1972	225.6	185.3	156.5	84	53.7	15.4	23
1973	187.8	156.6	129.8	82	49.5	8.5	26
1974	146.1	136.6	123.7	90	16.9	5.5	11
1975	84.1	84.1	77.1	91	7.0	0.0	8
1976	122.4	122.4	113.6	92	8.8	0.0	7
1977	196.1	191.7	160.3	83	31.4	4.4	16
1978	105.0	102.3	86.7	84	(15.6)	2.7	(15)

Adapted from ODFW & WDF, 1979.

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Table 5-4. Estimated numbers of winter steelhead (in thousands) in the Columbia River System, from FY 1953-54 to 1977-78[a] (adapted from ODFW & WDF, 1979).

Winter of	Catch: Commercial Gill Net	Catch: Sport (Oregon and Wash.)	Counts at dam: Marmot (Sandy)	Counts at dam: North Fork (Clackamas) Dam	Counts at dam: Mayfield (Cowlitz) Dam	Counts at dam: Willamette Falls Dam	Hatchery returns: Big Creek (Oregon)	Hatchery returns: Klaskanine (Oregon)	Hatchery returns: Eagle Creek (Clack)	Hatchery returns: Total	Hatchery returns: Percentage return to hatcheries
1953-54	23.4	48.2	--	--	--	5.2	--	--	--	76.9	--
1954-55	16.4	31.3	--	--	--	2.0	--	--	--	49.7	--
1955-56	11.6	38.4	2.2	--	--	3.8	--	--	--	56.0	--
1956-57	10.7	30.9	2.1	--	--	7.5	--	--	--	51.2	--
1957-58	6.8	37.7	3.1	1.6	--	5.6	--	--	0.1	54.9	--
1958-59	7.0	34.2	2.4	0.5	--	3.7	0.2	--	0.4	48.4	1.2
1959-60	6.3	49.1	1.6	1.2	--	2.2	0.3	--	0.3	61.0	1.0
1960-61	9.6	34.4	3.1	2.2	--	6.5	0.1	--	0.6	56.5	1.2
1961-62	9.9	57.7	4.0	4.4	10.7	5.9	0.3	0.3	1.2	94.4	1.9
1962-63	7.8	54.1	3.3	2.3	7.5	1.0	0.4	0.2	2.1	78.7	3.4
1963-64	5.4	52.6	3.9	1.9	11.5	0.9	2.5	0.0	0.7	79.4	4.0
1964-65	9.5	46.4	5.5	1.5	13.1	1.5	1.1	--	1.4	80.0	3.1
1965-66	8.0	76.6	3.6	1.3	11.2	14.7	4.3	--	0.6	120.3	4.1
1966-67	8.4	76.4	4.7	0.7	19.0	14.6	4.4	4.2	1.3	133.7	7.4
1967-68	8.4	70.6	2.9	0.8	14.1	6.4	5.6	3.0	0.3	112.1	7.9
1968-69	12.8	79.0	3.2	2.3	10.9	8.4	4.9	1.9	0.5	123.9	5.9
1969-70	3.6	47.0	2.4	2.8	3.5	4.7	2.5	1.2	0.0	67.7	5.5
1970-71	5.0	92.3	--	4.4	6.0	26.3	3.2	0.3	0.1	138.6	2.6
1971-72	8.6	126.2	--	2.8	6.0	23.2	1.8	1.5	1.1	170.2	2.6
1972-73	2.3	82.5	--	1.9	6.8	17.8	2.6	1.0	1.1	116.0	4.1
1973-74	2.4	61.0	--	1.5	8.5	14.8	3.5	1.1	0.4	93.2	5.4
1974-75	0.1	57.2	--	1.6	10.0	6.1	2.6	1.0	1.6	80.3	6.5
1975-76	0.0	43.5	--	1.2	7.1	9.4	2.2	0.8	0.8	65.0	5.8
1976-77[b]	0.0	37.7	--	1.5	4.9	13.6	0.9	0.8	0.3	59.7	3.4
1977-78[b]	0.0		4.0	1.9	19.4	16.7	0.6	0.8	1.3	(44.7)	6.0

[a] No data available on escapements into the major Washington tributaries (Grays, Elokomin, Toutle, Kalama, Lewis, and Washougal rivers) or escapements into minor tributaries in Washington (Abernathy, Cedar Creek, Coweeman, Germany Creek) or minor Oregon tributaries (Lewis & Clark, Clatskanie, Scappoose Bay tributaries, lower Clackamas tributaries).

[b] Incomplete data.

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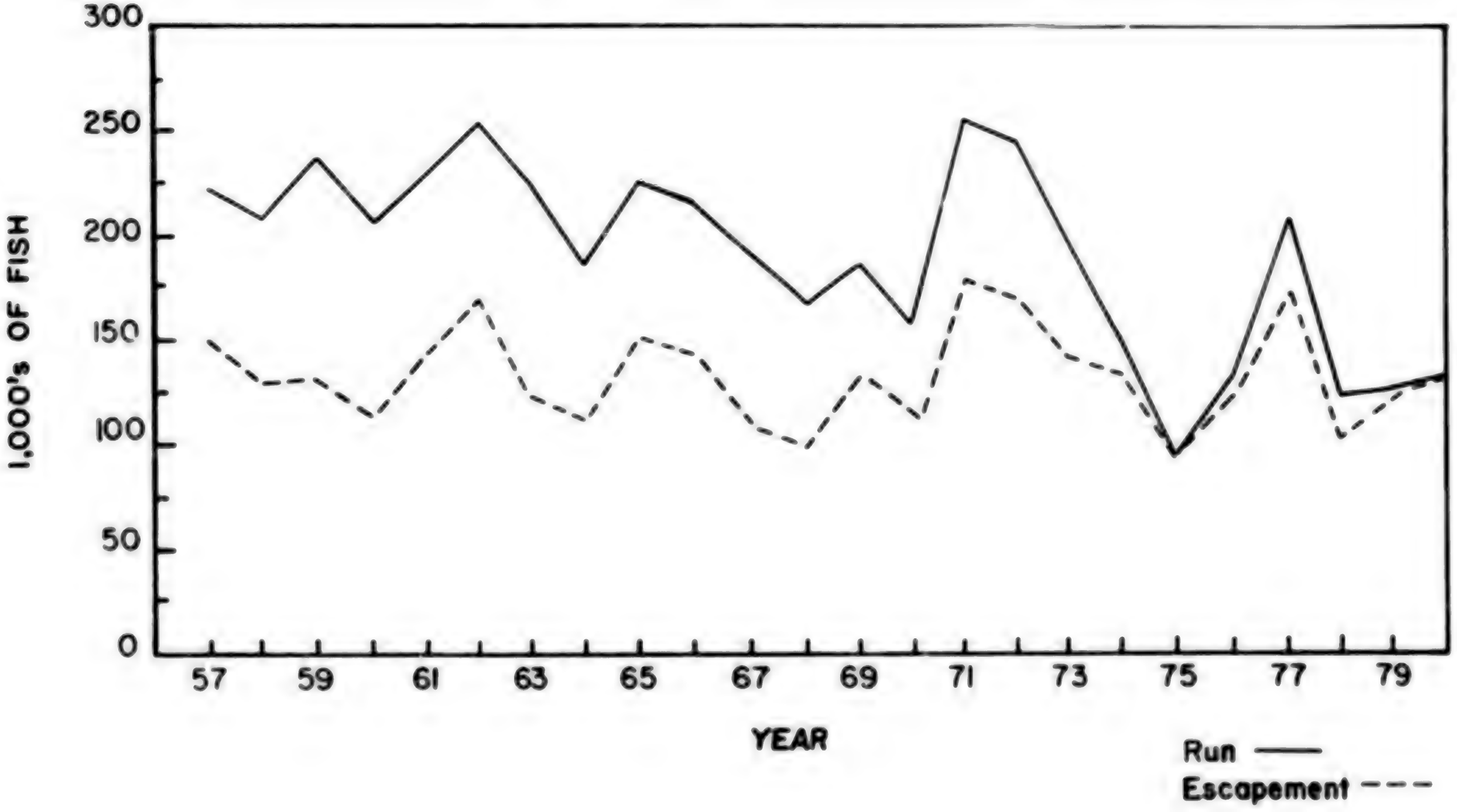

Figure 5.4. Estimated numbers of summer steelhead trout entering the Columbia River and escapement above Bonneville Dam, 1957-79.

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mortality and migration impediment (Buchanan 1977). As indicated by Table 5-4, this is evidenced by an average return-to-hatchery rate of 4.7 percent annually during the period 1969-1978. Salmonid return rates for successful populations are generally considered to be in the vicinity of one percent of the total population returns.

The summer run population has been drastically reduced in number due to the cumulative effects of main stem dams along the Snake and Columbia rivers. As Table 5-3 indicates, upriver summer runs which pass over the Bonneville Dam alone have experienced an average mortality rate of 13.3 percent annually. Summer run steelhead bound for spawning areas above the confluence of the Snake and Columbia rivers must pass over four additional dams, which could result in dam related mortalities as high as 73 percent of the spawning population. Adult steelhead destined for these spawning areas are being considered for endangered or threatened status (Columbia River Fisheries Council 1980).

Steelhead return to spawn in their natal streams. Spawning adults spend from two to three years as juveniles in streams and two to three years as adults at sea (Hart 1973). Movement at sea is extensive and is reviewed by Hart (1973) and Scott and Crossman (1973).

Winter steelhead have an extended run, which occurs from November through March or April, with peak numbers of fish occurring in January and February. Fish in these runs are primarily headed for tributaries and hatcheries below Bonneville Dam.

A few are destined for tributaries below Bonneville Dam, but most are destined upriver and must pass through fish ladders at each of the main stem dams. An early, smaller segment of the summer run is destined for tributaries along the middle and upper portions of the Columbia and Snake rivers drainages. A larger, later summer steelhead run is destined for the Clearwater River drainage in Idaho (Buchanan 1977).

Steelhead trout are widely distributed in the Columbia River, and their distribution is similar to that of spring Chinook salmon. Because they migrate and spawn before seasonal low-water periods, steelhead have fared better than spring Chinook in some areas where water is heavily used for irrigation (Fulton 1970).

5.4.4 Life History

Winter steelhead and the early summer run fishes spawn in the lower Columbia River and in stream tributaries with outlets into the estuary. The late summer runs are destined to upriver spawning areas. Although these runs migrate during different seasons, they spawn at the same time, winter and spring. Approximately one-half of the Columbia River basin steelhead production is currently of hatchery origin (Columbia River Fisheries Council 1980). Hatchery production occurs in the Youngs River, Big Creek, Gnat Creek, Cowlitz River, Green River, Clackamas River, Santiam River, Willamette River, Washougal River, Deschutes River, Snake River, Payette River, and Entiat River.

Females typically have 2,000 eggs per kg (2.2 lbs) of body weight (Moyle 1976). Following exterior fertilization, eggs hatch in three to four weeks. The fry remain in the stream bed for an additional two to three weeks. Spawning steelhead require clean, cool, and well aerated running water over coarse gravel for successful reproduction. Temperature and water quality requirements for successful steelhead spawning are similar to those required by other anadromous salmonids and are described in preceding sections of this report.

Most growth to adulthood occurs in the marine environment. Juvenile steelhead migrate to sea after attaining body lengths of 13 to 25 cm (5 to 10 inches). Typically they return to spawn measuring 38 to 69 cm (15 to 27 inches) weighing 1.4 to 5.4 kg (3.1 to 11.9 lbs).

5.4.5 Food Habits

Adults and juveniles apparently do not feed in the estuary (Costello 1977). Adults feed principally on fishes (young greenling, paralipids, sand lance, eulachon) and various crustaceans. Juveniles have feeding habits similar to resident trout. Their diet varies considerably according to season and rearing area. Trichoptera, ephemeroptera, diptera, and terrestrial insects are major prey items (Bell 1973). Food habits in marine and river habitats are detailed by Hart (1973), Scott and Crossman (1973), Bell (1973), Costello (1977), and Moyle (1976).

5.4.6 Factors Affecting Distribution and Abundance

5.4.6.1 Natural factors. Much of the discussion regarding natural limiting factors presented in the Chinook and coho sections also applies to steelhead trout. Tolerance of the steelhead to thermal and toxic conditions and their water quality requirements, such as dissolved oxygen, are also similar (Bell 1973).

5.4.6.2 Human factors. Like spring and summer Chinook salmon, steelhead suffer significant dam related mortality and access problems, but to a more limited degree because they usually migrate and spawn before seasonal low water periods.

There is little doubt that summer steelhead and the upriver runs of winter steelhead are limited by dam related mortalities to juveniles largely due to hydroelectric dam turbine blade inflicted injury, shock, and subsequent predation. Mortalities and impediment to adults on the upriver runs also play a role in limiting these populations. The result is a continued, chronic reduction of upriver stocks (Columbia River Fisheries Council 1980). The remaining natural spawning areas above Bonneville Dam are currently underutilized and do not limit reproduction (Fish and Wildlife Committee 1979).

The description of impacts caused by dams provided in the Chinook section are applicable to steelhead since they suffer the same problems with elimination of access to spawning areas, gas bubble disease, turbine blade related mortalities, residualism, and migration delays (Buchanan 1977; Columbia River Fisheries Council 1980).

The lower river winter steelhead populations offer a substantially different set of conditions. These runs are not blocked by dams. Run populations are more apt to be limited by hatchery production, the relatively low availability and poor condition of spawning habitats, and poor summer water quality conditions in freshwater rearing areas. Native American net fisheries can limit populations in some streams, but the sport catch is generally considered of negligible impact on steelhead populations.

Unlike salmon, steelhead are not taken commercially or recreationally in great numbers in ocean waters. There are native American net fisheries (between the Bridge of the Gods on the Bonneville reservoir and the mouth of the Umatilla River) and many sport fisheries for this species in riverine habitats. Return rates of adult steelhead are variable, but an average total population of one percent is not uncommon. Return rates are typically higher than those for salmon species. Unlike salmon, steelhead do not always die following spawning and may return to spawn a second or third time. The percentage that survive to spawn more than once is usually small.

5.5 WHITE STURGEON

5.5.1 Introduction and Description

The white sturgeon (Acipenser transmontanus) and the green sturgeon, A. medirostris are the two species of sturgeon found in the Columbia River Estuary. Sturgeon are large, primitive fish grouped with the paddlefishes, African bichirs, and numerous fossil fish. The white sturgeon is believed to grow to a very old age (100 years+) and is the largest freshwater fish in North America. It is reported to grow as large as 820 kg (1,800 lbs) with verified records of 590 kg (1,300 lb). Fish this large, however, have not been captured in many years (Moyle 1976).

Sturgeon are anadromous and possess rounded snouts and four barbels in a traverse row on the underside of the snout in front of the mouth. They have five separated rows of bony plates running lengthwise along their bodies, each plate having a sharp spine on the back edge. White sturgeon are generally grey with white underbellies. The green sturgeon is similar in appearance except that it is smaller, has a long narrow snout, and its body color is olive green. It is not nearly as significant a commercial or sport fish as the white sturgeon and is not described in this report.

5.5.2 Resource Value and Estuary Usage

The white sturgeon is highly regarded for its flesh and its eggs, from which caviar is made. Average annual landings for the last 30 years exceeds a quarter-million pounds in the Columbia River Estuary. Harvesting provides the greatest potential for mortality of this species. Little information is available on the significance of the Columbia River Estuary to the white sturgeon. Although anadromous, sturgeon spend most of their lives in fresh water (Kujala 1976). In the estuary, the lower range of sturgeon is usually from Chinook Jetty to Hammond. Trawlers catch white sturgeon in the ocean, but it is possible that these are sturgeons carried out of the river by strong runout tides and spring freshets. Large numbers of small (under-sized) sturgeon can be found in the estuary.

5.5.3 Population Status

Current population estimates for sturgeon are not available. Catch records (Table 5-5) indicate the presence of substantial numbers of white sturgeon in the lower reaches of the Columbia River. Populations are believed to be stable and in good condition (ODFW and WDF 1979). Annual catches between 1957 and 1978 average 167,409 kg (369,070 lbs). However, catches of the late 1800's were of a greater magnitude, peaking in 1892 with nearly 2.5 million kg (5.5 million lbs) catch (Alverson 1972). Current harvests for white sturgeon in the Sacramento-San Joaquin estuary are estimated at 70 percent of the average historic catch of 1875-1899 (Moyle 1976). If the 70 percent figure was applied to the Columbia River population, this would indicate historic populations of fish whose combined weight was greater than 454,545 kg (1 million lbs). The reduction in population may be due to harvest, but is more likely due to loss of spawning habitat.

Sturgeon occur throughout the main stem of the Columbia and Snake rivers. They concentrate in the area immediately downriver of Bonneville Dam as they attempt to migrate upstream to spawn.

White sturgeon at one time migrated long distances up the Columbia River as far as Montana. The installation of the main stem dams on the Columbia and Snake rivers has largely curtailed their migrations. Some fish may be able to move through the navigation locks, but their numbers are probably small. Moyle (1976) reports adult white sturgeon to be primarily estuarine, while Scott and Crossman (1973) report them to be a primarily oceanic species. The notion of the white sturgeon as an oceanic species is supported by the absence of PCB's in some individuals, as documented by recent analysis. Movement in the sea is not well known and is thought to be mostly local, although distances of 1056 km (660 mi) have been recorded (Chadwick 1959). It is likely that some populations are marine oriented while others remain in estuaries. Adults are reported to enter rivers largely in the spring, but records indicate entrance into freshwater during fall and winter (Scott and Crossman 1973). They typically spawn in May through July.

There are landlocked sturgeon populations in existence above the main stem dams of the Columbia River. Movement, if any, is poorly documented for these populations. In some freshwater rivers, small sturgeon have been observed moving upriver during fall and early winter and downriver during late winter and early spring. Other nebulous patterns include movement from deep water in winter to shallow water during summer, and toward the ocean in summer and upriver in winter (Migdalski 1962).

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Table 5-5. Landings (in thousands of pounds) of white and green sturgeon in the Columbia River, 1957 to 1978.

Year	White sturgeon Below Bonneville Dam	White sturgeon Above Bonneville Dam	White sturgeon Total	Green sturgeon total
1957	303.6	8.1	311.7	112.8
1958	237.1	19.7	256.8	76.6
1959	167.5	35.9	203.4	192.2
1960	173.1	11.0	184.1	71.3
1961	174.0	9.3	183.2	119.2
1962	196.5	4.1	200.6	65.3
1963	207.8	4.2	212.0	50.3
1964	135.8	3.8	139.6	30.0
1965	150.1	7.9	158.0	32.4
1966	221.2	5.0	226.2	70.9
1967	151.1	8.6	159.7	46.1
1968	141.1	10.6	151.7	24.7
1969	293.4	16.6	310.0	68.4
1970	250.1	15.3	265.4	51.1
1971	280.2	31.3	311.6	52.4
1972	297.5	30.5	328.0	46.2
1973	389.5	41.5	431.0	34.5
1974	345.0	26.6	371.6	121.8
1975	454.5	29.3	483.8	42.9
1976	732.7	24.4	757.1	89.5
1977	320.7	16.2	336.9	23.5
1978	(287.9)	(20.4)	(308.3)	(49.2)

Source: ODFW & WDF 1979.

Very little is known about marine populations, their mortality, or the effect of predation on these. No commercial fishery has developed for this species outside the lower river area, although an occasional large sturgeon is taken recreationally far upriver.

5.5.4 Life History

Little is known about the spawning of white sturgeon. The spawning period is May through July and is thought to occur over rocky gravel bottoms in deep holes at the base of waterfalls, major eddy pools, and possibly dams. Scott and Crossman (1973) have reported spawning temperatures from 8.9° to 16.7°C (48° to 62°F), while Moyle has reported a 10° to 24°C (50° to 75°F) range. Little is known about hatching time or other juvenile life events.

Females are usually 11 to 12 years old before becoming sexually mature, while males mature at a younger age (Moyle 1976). Adults survive the spawning process and return to spawn at increasingly longer time intervals (every four years in young females and every nine to 11 years in older females).

White sturgeon are very prolific, with fecundity proportional to age and size. Young females of 1.1 to 1.5 m (3.6 to 4.9 ft) produce about 100,000 eggs per spawning while older, larger females yield from three to five million eggs per spawning.

Generally, white sturgeon achieve a length of about 60 cm (20 inches) by age five and grow about 50 mm (2 inches) per year until about age 25. The growth rate of body length decreases after age 35, and further growth results in increased weight. An individual 3.5 meter (11.5 feet) in length, from the Columbia River was estimated at 82 years of age (Scott and Crossman 1973).

5.5.5 Food habits

Columbia River Estuary white sturgeon are primarily bottom feeders, typically eating a variety of bottom-dwelling invertebrates such as sand shrimp (*Crangon* sp.), amphipods (*Corophium* spp.), various polychaete and oligochaete worms, mysids including *Neomysis mercedis*, and clams, notably *Corbicula* sp. White sturgeon also consume several small fish, including northern anchovy (*Engraulax mordax*) and the long fin smelt (*Spirinchus thaleichthys*). Adults are opportunistic feeders, but are the most piscivorous of sturgeon species.

5.5.6 Factors Affecting Distribution and Abundance

5.5.6.1 Natural factors. Little is known about mortality rates, but natural predation is believed to be slight. Adult predation on juveniles is documented by Scott and Crossman (1973). Natural mortality appears to be low, and food supplies seem to be adequate.

5.5.6.2 Human factors. White sturgeon of the lower Columbia River exemplify a valuable fishery being nearly eliminated by overharvesting.

White sturgeon are harvested commercially and recreationally in the lower Columbia River and Estuary. This harvest is probably the largest single mortality factor for this species. Millions of pounds of sturgeon were harvested each year in the late 1800's. Harvest yields dropped off to about 45,000 kg (100,000 lbs) per year as early as 1899 (Alverson 1973). Harvests began improving in the 1920's and then dropped off again in the late 1930's and through the 1960's; harvests have again improved in the 1970's (ODFW and WDF 1979) (See Table 5-5). Due to the length of time (11 to 12 years) and size required before attaining sexual maturity, and the relatively infrequent spawning per individual, sturgeon are highly susceptible to overharvesting.

Like other anadromous fish, this species has been seriously affected by Columbia and Snake rivers main stem dams. As Scott and Crossman (1973) state: "The most serious limitation to this anadromous species may be the physical and ecological barriers created by dams and their impoundments". Another potential long-term effect of dams is the establishment of a number of isolated small populations upriver which are prone to deleterious genetic effects including genetic drift, fixing of harmful genes, reduced genetic diversity, inbreeding, and others. These effects are discussed by Franklin (1980).

Since sturgeon grow to be quite old, and are near the top of the food web, they should be theoretically susceptible to long-term bioaccumulation of toxic substances. However, since a portion of the population spends much of its adult period in Pacific Coast oceanic communities were pollutant levels are relatively low, quantities of ingested toxic substances do not appear to be a serious limiting factor.

5.6 AMERICAN SHAD

5.6.1 Introduction and Description

The American shad (Alosa sapidissima) is a large, thin, silvery, herring-like fish with large scales. It is characterized by a steely-blue back, a row of spots decreasing in size from behind the gill along the lateral line, and spine-like scutes along the belly.

The American shad is anadromous and native to the Atlantic coast. It was successfully introduced into the Columbia River and other rivers of the west coast, most notably the Sacramento River of California, in the late 1800's (Moyle 1976).

5.6.2 Resource Value and Estuary Usage

Shad are considered a prized fighting fish for catching on artificial flies and lures. Commercially, the shad is principally sought after for the roe (eggs) of the female. The commercial season for shad in Youngs Bay, the John Day River, and Grays Bay is normally from mid-May to mid-June. Catches of 1973 totalled 94,227 kg (207,300 lbs) of which 96 percent were roe shad.

Migrating adult shad are found throughout the estuary from late April through June with higher concentrations found in the main channels leading upstream. Other concentrations are found in Youngs Bay, John Day River, and Gray's Bay. Youngs Bay is known as a habitat for juvenile shad (Higley and Holton 1975; Kujala 1976). Immature shad can be taken throughout the year in the lower estuary. These juvenile shad typically migrate to sea in late fall or early winter, but some fish from lower Columbia River tributaries migrate in May or June.

5.6.3 Population Status

Population trends for this species in the Columbia River system, as indicated by the number and weight of fish landed, are summarized in Table 5-6. Populations in the Columbia River system seem to be increasing and are stable in California and British Columbia (Scott and Crossman 1973; Moyle 1976). In recent years, runs of over a million fish have been reported to have passed over the Bonneville and Dalles Dams (ODFW and WDF 1979).

No shad population existed above Celilo Falls until the Dalles Dam flooded in the fall of 1957, at which time large numbers of adults were able to pass the dam. Slack water impoundments have provided suitable habitats for both spawning and rearing. As a consequence, shad are now found in the upper Columbia and Snake rivers.

5.6.4 Life History

The species is anadromous and spawns in freshwater sloughs from Youngs Bay to above McNary Dam. Water temperature seems to be a key factor for the timing of runs, because shad do not usually move into freshwater until temperatures exceed 11°C (52°F) with peak numbers of fish occurring at temperatures between 15° to 20°C (59° to 68°F) (Moyle 1976).

Oceanic movement of shad is not well documented in the Pacific Ocean, but is reported to be widespread in the Atlantic and particularly extensive along the coast. The current wide distribution of shad along the Pacific coast indicates a similarly extensive migration probably takes place here as well.

Migrating adults in the estuary and river travel mainly in large channels. Adult runs are typically segregated by sex, with males usually running first. Most of the runs are destined upriver beyond Bonneville Dam, but spawning also occurs in the Youngs, Walluski, Lewis and Clark, Deep, and Grays rivers, and in slow moving sloughs near the head of tidewater (Buchanan 1977).

Juvenile shad of Columbia River tributaries typically migrate to sea in late fall or early winter, with migration peaks observed in November and January, although some fish of lower tributaries migrate in May or June (Kujala 1976).

The American shad spawns in a wide range of freshwater habitats, but spends most of its adult life in marine habitats. Jordan and Evermann (1923) report that they seem to prefer shallow flats near creek mouths.

Table 5-6. Landings (pounds and number x 1000) of shad in the Columbia River 1957 to 1978.

Year	Pounds landed	Numbers landed
1957	150.1	40.0
1958	193.4	51.6
1959	135.6	36.2
1960	170.3	45.4
1961	406.2	108.3
1962	894.4	238.5
1963	859.3	229.1
1964	305.3	81.4
1965	354.9	94.6
1966	786.4	209.7
1967	853.2	227.5
1968	310.8	82.9
1969	178.8	47.7
1970	250.7	65.5
1971	180.0	47.0
1972	233.5	60.2
1973	210.7	53.9
1974	195.2	49.5
1975	269.7	73.0
1976	303.9	80.3
1977	(243.3)	(63.0)
1978	(453.3)	(117.4)

Source: ODFW & WDF 1979.

The ODFW and WDF (1979) report that reservoirs behind the numerous hydropower dams along the Columbia system are providing suitable spawning habitat. Moyle (1976), however, reports that shad spawn in main river channels.

Spawning usually takes place in early evening hours (Scott and Crossman 1973; Moyle 1976). A female is usually accompanied by several males; she swims vigorously along the surface and releases eggs to the water column as the males press against her. The males simultaneously release their milt.

This event involves large numbers and results in a large school of fish, wildly jumping, swimming, and thrashing. The adults repeatedly spawn until each of the females has released her 30,000 to 300,000 eggs. Most of the adult shad are thought to survive spawning in the Columbia River system, but in more southerly areas, they typically die following spawning. (Cheek 1968; Scott and Crossman 1973; Moyle 1976). It appears that postspawning mortality rate is proportional to water temperatures. In cooler waters and higher latitudes, shad have been reported to spawn as many as five times (Scott and Crossman 1973).

Spawning does not start until temperatures have reached 12°C (53.6°F), with peak spawning occurring at 18.3°C (65°F) (Scott and Crossman 1973). Fertilized eggs are approximately 3.5 mm (0.1 in) in diameter and are translucent with a pale pink or amber tinge. They are nonadhesive and slightly heavier than water. Hatching takes place in 8 to 12 days following spawning at temperatures of 11° to 15°C (51.8° to 59.0°F) (Scott and Crossman 1973). At hatching, the larvae measure 1 cm (0.4 in).

Juveniles triple their length from 1 to 3 cm (0.4 to 1.2 in) during their first month. By the time they enter salt water, they are 8 to 18 cm (3 to 7 in) in length (Moyle 1976). Shad reach to 7.5 to 17.5 cm (3 to 7 in) in length by the end of the first growing season. Two-year-old fish can be expected to grow to about 23 cm (9 in), three-year-olds to about 30 cm (12 in), and four-year-olds to about 43 cm (17 in). Hart (1973) reported that some shad grow as large as 58.4 cm (23 in) long.

Males are typically mature at four years while females mature at five years. In the Columbia River system, males spawn in their fifth year and females in their sixth year. Shad are sexually dimorphic, with adult males characteristically weighing one pound while females weigh four pounds or more (Kujala 1976).

It has not been clearly documented that American shad return to their parental waters to spawn, but considering their extraordinary abilities to navigate and their sensitivity to minor water parameter changes (Leggett 1973), homing behavior is likely.

5.6.5 Food Habits

Food habits for Columbia River American shad have not been determined. Adults may or may not feed during the initial portion of their upriver migration, but are thought to feed during downriver postspawning runs.

Adult shad in the Sacramento-San Joaquin delta feed on large zooplankton. The most abundant dietary component is the oppossum shrimp, Neomysis mercedis, followed by copepods, cladocerans, and amphipods (Moyle 1976), which are common to the Columbia River Estuary. In the same area, juveniles feed in surface waters on zooplankton, especially Neomysis, copepods, and amphipods. Occasionally, they will take benthic organisms such as chironomids and other insects. Juvenile shad in the Columbia River Estuary have been shown to feed heavily or the amphipod Corophium salmonis (Durkin et al. 1977).

5.6.6 Factors Affecting Distribution and Abundance

5.6.6.1 Natural factors. There is little information regarding natural limiting factors for the American shad in the Columbia River. As mentioned in the section on life history, shad spawning is reduced at temperatures above 20°C (68°F). At higher temperatures, post-spawning mortality increases. Shad seem to have very low parasite infestation rates and do not seem to be limited by disease. Predation on adults and juveniles also appears to be relatively light. Seals are one of the few known natural predators of shad. Predation on juveniles in riverine and estuarine systems has not been observed, but is expected to occur.

5.6.6.2 Human factors. The American shad was introduced to the Columbia River system in the late 1800's and has adapted well to the changing hydrologic conditions related to dams of the watershed. Most of the past effects of human activity on the shad in this system seem to have been beneficial as populations are large and show signs of increase. Commercial harvest is a major source of adult mortality with over 204,545 kg (450,000 lbs) taken during 1978 (ODFW and WDF 1979). Approximately 20,000 fish are also caught annually for sport.

In their native areas of the Atlantic coast, American shad have been adversely affected by impassable dams and degradation of water quality (Scott and Crossman 1973); they have nearly disappeared from some rivers. However, they have been able to persist in many of the dammed rivers due to their ability to spawn in slightly brackish waters near the head of tidewaters. They are able to ascend fishways that are well constructed and do not require leaping ability (Rounsffell 1975). Adults are also known to use lock systems to bypass dams (ODFW and WDF 1979). Serious adverse impacts to juveniles of dam related mortality, such as turbine blade damage or gas-bubble disease, are not documented.

This species' sensitivity to various water quality parameters has not been reported in the literature. Laboratory studies on the sensitivity of fish to heavy metals, pesticides, sediments, dissolved oxygen, and pH are given by Bell (1973), USEPA (1977), Dvorak et al. (1978), Johnson and Finley (1980), and Soholt et al. (1980).

5.7 DUNGENESS CRAB

5.7.1 Introduction and Description

The Dungeness crab Cancer magister is a large, edible crab primarily valued as a food resource. It is light reddish brown in color and possesses white-tipped claws. Males are larger than females, weigh over 1 kg (2.2 lbs), and may have carapace widths of 18 cm (7 inches) or more.

This species inhabits sandy and muddy marine and estuarine habitats from the intertidal zone to offshore depths of 170 m (558 ft) (OSU 1971). Dungeness crabs reportedly range from the Aleutian Islands, Alaska to Magdalena Bay, Mexico (Rees 1963; MacKay 1942), but are rarely encountered south of Point Conception, California (Pacific Fishery Management Council 1979).

5.7.2 Resource Value and Estuary Usage

Male Dungeness crabs constitute a recreationally important and commercially substantial fishery resource in the Pacific Northwest region. The mouth of the Columbia River Estuary is a prime fishing area, and Dungeness crabs are regularly found in Baker and Youngs Bays. Adults principally inhabit deep channels of the estuary seaward of Hammond and the Chinook jetty (Seaman 1977). Juveniles may be found as far as 24 km (15 mi) upriver. Immature adults may stay in estuarine channels and move up and down rivers with the tides, but after a year they stay within harbors (Stevens, Univ. of Washington College of Fisheries; pers. comm.).

5.7.3 Population Status

Dungeness crab population estimates can be roughly made from an analysis of catch records. The status of female crabs is not known because they are not harvested. The catch ranges from well over 23 million kg (50 million lbs) to a low of 4 million kg (8 million lbs) in the region. The Oregon Fish and Wildlife Commission estimates that 95 percent of legal size males are caught annually. Based on the history of the fishery, crab landings are expected to decline until the early 1980's before rebounding (PFMC 1979).

Dungeness crab fishery stocks exhibit variable, but cyclical fluctuations in harvest abundances (PFMC 1979; McKelvey et al. 1980). The periodicity of these fluctuations is about nine years (Botsford and Wickham 1975). Specific causes of these fluctuations are not yet known, but factors such as rainfall (Lough 1975), nutrient upwelling (Peterson 1973), fishing pressure, and density dependent controls including cannibalism and egg predation (Botsford and Wickham 1975) have been proposed.

5.7.4 Life History

Male and female crabs are sexually mature at three and two years age, respectively, and live eight to ten years (Isakson 1976). Adult crabs are polygamous, and spawning takes place at marine salinities, as the eggs and larvae cannot tolerate freshwater (Stevens, pers. comm.). Mating occurs from April to August in coastal shoal waters (OSU 1971; Rounsffell 1975). Females brood fertilized eggs in an abdominal egg mass for about three months. Larval development takes about 100 days and proceeds from a planktonic to a benthic existence. Embryonic larvae hatch as zoea between May and October.

Megalops larvae are highly stenohaline, exhibiting optimum development in waters ranging from 25 to 30 ppt in salinity (Reed 1969). Juveniles exhibit the greatest salinity tolerances and are found in estuaries in which salinities may be lower than 10 ppt. It is within estuaries that Mayer (1973) observed juvenile molts in January, May, and August. Adult crabs, although also tolerant of brackish water, prefer high salinities of lower estuarine reaches and must return to highly saline waters to spawn.

5.7.5 Food Habits

Dungeness crabs are an integral part of marine and esturine food webs. Zoea larvae feed on phyto- and zooplankton. Megalops feed on small crustaceans, crab eggs, and plankton, while juvenile feeding habits are variable and site-specific. They are primarily opportunistic predators. Major food items of adult diets include clams, isopods, amphipods, polycheate worms, shrimp, small crabs, and barnacles (MacKay 1942; Butler 1954). Table 5-7 shows the dietary spectrum of crabs.

Stevens et al. (in press) indicate that there is an ontogenetic switch in food preferences with body size. In the outer portion of Grays Harbor small crabs (less than 60 mm) preyed mostly on molluscs and crustaceans, but ate few fish or *Crangon*; medium crabs (61-100 mm) showed increased predation on fish and *Crangon*, but less on bivalves; and large crabs (greater than 100 mm) preyed mostly on fish, less on crustaceans, and very little on bivalves. Inner harbor crabs exhibited almost identical feeding habits with the exception that in small crabs amphipods and additional crustaceans replaced molluscs (Stevens pers. comm.). Shiner perch, sand lance, and English sole are the most frequently consumed, with all demersal fish accounting for 60 to 70 percent of crab diets.

5.7.6 Factors Affecting Distribution and Abundance

5.7.6.1 Natural factors. Water temperature, salinity, upwelling conditions, and/or predation are instrumental factors influencing abundances of Dungeness crabs. Temperature and salinity strongly affect breeding and migratory behavior.

Water depth and chemistry also influence distribution patterns. For example, crabs occur to 229 m (750 ft) depths, but they are not abundant below 91 m (300 ft) (Frey 1971).

Crab movement patterns have been investigated in some estuaries (OSU 1971; Stober and Salo 1973; Mayer 1973), but are generally unknown in the Columbia River Estuary.

Natural mortality is also poorly understood. Larval and juvenile mortality varies, but is very high (99 percent) (Mayer 1973). In one-year-old crabs or younger recruits, cannibalism has been frequently observed. Some mortality is caused by "black spot" or "rust spot" disease. Jow (1965) from mark recapture data estimated a 15 percent natural mortality rate in a harvested crab population near the California-Oregon border. The overall causes of adult natural mortality, however, remain unknown (Mayer 1973).

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Table 5-7. Food habits of the dungeness crab.

Author	Date	Location	Number	Frequency of occurrence (%) Crustacea	Bivalves	Fish	Other foods		Size range of crabs
Mackay	1942	British Columbia		(1)	(2)		(3) Polychaeta		
Butler	1954	Hecate Strait	170	62	51	2			
Tegelberg	1972	Washington Coast	264	34	65	33			All crabs over 110 mm
Mayer	1973	Similk Bay, WA	50	(1)	(2)				
Gotshall	1977	N. California Humboldt Bay	168 40	-- 38	46 62	24 87			
Bernard	1979	Hecate Strait	202	--	--	--	*Cragnon* *Siliqua* *Tellina*	24% 22% 20%	
Feder and Paul	1980	Cook Inlet, AK	349	30	67	2	*Spisula*	48%	All over 50 mm
			64	--	25	0	Forams	36%	Less than 50 mm
							Barnacles Polychaeta	28% 28%	

( ) Rank shown in parentheses.
-- Data not convertible to frequency of occurrence.

Source: Stevens et al. (in press).

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Predators of Dungeness crab larvae include fish such as coho and Chinook salmon, ling cod, herring, pilchard, mackerel, and wolf eel. Seabirds also consume larvae, as does the seastar, Pisaster bervispinus, (Van Veldhuizen and Phillips 1978). Predators of adult crabs are wolf eel, cod, spiny dogfish, octopus, and other crabs (Dean 1971). The small nemertean, Carcinonemertes errans, lives on Dungeness crabs and is an important egg predator (Wickham 1979).

5.7.6.2 Human factors. The crab fishery presently has the greatest effect on Dungeness crab abundances. Crab stocks are sustained, despite an estimated 95 percent fishery harvest of adult males. Fishery mortality rates have been previously estimated at 74 to 84 percent (Cleaver 1949) and 84 percent (Jow 1965). There is concern among crab fishermen over the rapidly expanding salmon aquaculture industry, as they believe increased salmonid predation on crab megalops may be detrimental to crab populations (PFMC 1979).

In an evaluation of channel maintenance dredging in Grays Harbor, Washington, hopper dredging was found more damaging to Dungeness crabs than pipeline dredging (Tegelberg and Arthur 1977). In a more recent study, Stevens (pers. comm.) determined clamshell dredging to be the least harmful.

Laboratory studies have been conducted to determine the presence of insecticides in Dungeness crabs (Buchanan et al. 1970; Armstrong et al. 1976; Caldwell et al. 1978), but data on crabs inhabiting the Columbia River Estuary and vicinity are sparse. Dead Dungeness crabs were noted on an Oregon oyster ground that had been treated with Sevin to extirpate burrowing ghost and mud shrimp (Buchanan et al. 1970). Overall, many insecticides are harmful even in extremely low concentrations. There is no evidence to suggest that their presence in the Columbia River Estuary may influence larval or adult crab abundance or distribution. In contrast, pesticide surveys of Dungeness crabs in San Francisco Bay, California have revealed the presence of DDT and elevated levels of cadmium, silver, and selenium (Wild et al. 1978). Juvenile crabs from San Francisco Bay also acquire large hydrocarbon burdens (PFMC 1979).

5.8 COROPHIUM SALMONIS

5.8.1 Introduction and Description

Corophium salmonis is a small bottom-dwelling crustacean of light brown color that is approximately 1 cm (0.4 inches) in length. Preferring fine sand and unvegetated mudflats (Holton and Higley 1976) in which to build mucus-lined U-shaped burrows, they nevertheless are found within muddy deposits of sheltered areas and in both intertidal and subtidal soft sediments (Davis 1976 in Holton 1981). Frequently, Corophium salmonis is seen crawling over the substrate or swimming freely in the water.

5.8.2 Resource Value and Estuary Usage

Amphipods, particularly the species Corophium salmonis, are an ecologically important invertebrate of littoral and sublittoral portions of the

Columbia River Estuary because of their abundance in surface sediments, their consumption of large quantities of detritus, and their being eaten almost exclusively by foraging fish and shorebirds. At densities of 10 to 50 thousand/m^2 (930 to 4,650/ft^2) (Holton and Higley 1976), these detritivores play a key role in element and nutrient cycling and provide a year round food source for animals of higher trophic levels.

5.8.3 Population and Status

Corophium salmonis populations have been estimated to be 60 percent of the benthic macrofauna and exhibit average densities of 12,000 m^2 (1,116/ft^2) (Holton 1981). Densities vary with wave energy and substrate characteristics, but are independent of salinity. In brackish high energy waters of Baker Bay and in sediments at the mouth of the Columbia River, the lowest densities were observed about 400/m^2 (37/ft^2). In calm but brackish Youngs Bay, densities were highest and estimated at 7,000 to 42,000/m^2 (651 to 3,906/ft^2). In increasingly fresher water upstream from Youngs Bay, moderate densities of up to 9,000/m^2 (837/ft^2) were observed (Higley et al. 1976).

Vertical diel migrations are known to occur. At sunset *Corophium salmonis* leave their tubes and exhibit an active nocturnal swimming period at the surface (Davis 1976 in Holton 1981). Kujala (1976) found that most individuals in the upper water column were older juveniles, and thus hypothesized that diel activity may be a dispersal mechanism. Holton (1981), in a hypothesis consistent with Kujala, suggested that populations at some locations (e.g., Desdemona Sands) may be attributed largely to immigration from more stable habitats. Nighttime swimming by *Corophium salmonis* may also be advantageous in escaping predation by day-time feeding fish.

Long distance upstream or downstream movements no doubt occur and must be related to tidal conditions and streamflow. Rick Albright (Univ. of Washington College of Fisheries; pers. comm.) has noted increases in *Corophium salmonis* populations on sandy substrates between fine sediments in Grays Harbor and also horizontal migration among wintering *Corophium spiticorna* populations from the center of channels to the sides indicating that those amphipods readily move short to medium distances. It remains to be determined if *Corophium salmonis* actively uses currents for dispersal.

5.8.4 Life History

Early fall is hypothesized as the time of high recruitment because most of the swimming animals are juveniles, whereas the nonswimming substrate types were ovigerous females (Davis 1976 in Holton 1981). The high numbers at night suggest they are dispersing by tidal currents. Additionally, size frequency histograms indicate that the largest, greater than 5 mm (0.2 in) in length, animals die in October (Holton 1981), supporting the contention that overwintering populations are mostly smaller size classes.

Information on the reproductive behavior of *Corophium salmonis* within the Columbia River Estuary is rather sketchy. Sexual maturity is generally reached by six to eight weeks (Albright, pers. comm.), and syngamic reproduction occurs throughout the year as gravid females are collected in epibenthic and benthic strata during all seasons. Continuous recruitment results in numerous, overlapping age classes, although major cohorts are produced in spring and fall.

Copulation probably occurs in the water column because mature males and females may detect each other and copulate more readily in surface waters than within the substrate. Capture data by Davis (1976 in Holton 1981) of mating types support this hypothesis.

After copulation, female *Corophium salmonis* promptly release eggs from their oviducts into the brood pouch where they are fertilized. Overall clutch size counted by Davis (1976 in Holton 1981) was almost 16 eggs. The number of eggs released by females depends on age, the larger and older females releasing the larger number of eggs.

5.8.5 Food Habits

Corophium salmonis is basically a surface deposit feeding detritivore (Holton and Higley 1976). Antennae detect suspended food particles. Plant and animal matter are strained through fine hairs attached to the legs and subsequently eaten.

5.8.6 Factors Affecting Distribution and Abundance

5.8.6.1 *Natural factors.* Estuarine fish, shorebirds, and aquatic invertebrates feed on *Corophium*. Adult and immature Coho salmon feed extensively on *Corophium salmonis* as do juvenile Chinook. Durkin et al. (1977) reports 95 percent of Coho gut items, accounting for 85 percent of the weight, were *Corophium salmonis*. Fall juvenile in Youngs Bay exhibited 75 to 100 percent frequency of *Corophium* as gut items. These accounted for 80 to 100 percent of all organisms and 10 to 100 percent of total weight of gut items (Durkin et al. 1977). *Corophium* are also a major dietary component of starry flounder (*Platichthys stellatus*), longfin smelt (*Spirinchus thaleichthys*), Pacific staghorn sculpin (*Leptocottus armatus*), prickly sculpin (*Cottus asper*), shiner perch (*Cymatogaster aggregata*), Pacific tomcod (*Microgadus proximus*), and white sturgeon (*Acipenser transmontaus*).

Free living amphipods including *Eogammarus conferriculus* and *Anisogammarus* spp. are major winter predators on *Corophium salmonis* in Grays Harbor (Albright, pers. comm.) and probably also feed extensively on *Corophium* in the Columbia River Estuary. Another invertebrate predator, the sand shrimp (*Crangon* spp.), commonly found in the Columbia River Estuary to the open ocean, have been observed to feed on *Corophium* in tide pools (Albright, pers. comm.) and may be capable of decimating local populations.

Shorebirds feed on intertidal beaches and mudflats where large concentrations of *Corophium* are found. Large over-wintering flocks of sanderlings, dunlins, and other shorebirds with high metabolic rates rely on *Corophium* within the estuary to fulfill daily energy requirements.

Albright (pers. comm.), is convinced that predation is a major factor influencing the abundance of winter populations of *Corophium* in Grays

Harbor and conceivably may also be significant in the Columbia River Estuary.

Substrate characteristics (Holton and Higley 1976) and turbulence (Higley et al. 1976; Seaman 1977) are major natural factors influencing the distribution and abundance of Corophium. Salinity and other water quality parameters do not appear to be limiting factors.

5.8.6.2 Human factors. The greatest man caused impact to Corophium is the loss of habitat that results from filling tide flats. Apparently, Corophium is able to recolonize a dredge spoil area that does not extend 2.1 m (7 ft) above mean lower low water (somewhat higher in muddy areas) because water mobility within sediments of this depth can provide adequate moisture for Corophium survival (Albright, pers. comm.).

Fertilizer and pesticide runoff from agricultural lands and the discharge of industrial wastes may enter the river far upstream and conceivably influence the biology of amphipods and other widely distributed invertebrates in the estuary. However, because of the wide tolerance of Corophium salmonis to pollution (Albright, pers. comm.), they are not anticipated to change in numbers or habits.

5.9 WATERFOWL AND SHOREBIRDS

5.9.1 Introduction and Description

The lower Columbia River exhibits an impressive array of waterfowl and shorebirds. One species of grebe, 21 species of ducks, three species of geese, and one species of swan were observed by Tabor (1976) between the mouth of the Columbia Estuary and Portland (Table 5-8). Additionally, 16 species of shorebirds use open water, beaches, tidal marshes, and other estuarine habitats (Table 5-9).

5.9.2 Resource Value and Estuary Usage

Waterfowl have traditionally represented an important recreational resource of the Columbia River Estuary primarily because of their value to hunters. Waterfowl and shorebirds also possess important recreational and esthetic values to people spending their leisure time hiking, birdwatching, and photographing. Additionally, the ecological and scientific value of shorebirds has been established in papers by Holmes and Pitelka (1968), Baker and Baker (1973), Pitelka et al. (1974), and Ashkanazie and Safriel (1979a,b). These papers describe the feeding budgets and time energy allocation among shorebird species and assess the adaptive significance of the varying strategies. Acknowledgement of these nonconsumptive values justify the continued protection of waterfowl and shorebirds and their habitat.

Quantitative data describing avifauna use of the Columbia River Estuary are unavailable, with the exception of the Federal Wildlife Refuges. Data for the Lower Columbia Wildlife Refuge complex (primarily the Ridgefield and Clark Refuges) not only reflect refuge use, but also indicate the extent waterfowl and shorebirds provide recreational enjoyment within the estuary.

Table 5-8. Species of waterfowl observed in river mile segments of the Columbia River.

Species	River Mile 0-12	 12-79	 79-145
Western grebe (*Aechmophorus occidentalis*)	X	X	-
Whistling swan (*Olor columbianus*)	X	X	X
Canada goose (*Branta canadensis*)	X	X	X
White-fronted goose (*Anser albifrons*)	-	X	X
Snow goose (*Chen caerulescens*)	-	X	X
Mallard (*Anas platyrhynchos*)	X	X	X
Gadwall (*Anas strepera*)	-	X	X
Pintail (*Anas acuta*)	X	X	X
Green-winged teal (*Anas crecca carolinensis*)	X	X	X
Cinnamon teal (*Anas cyanoptera*)	-	X	X
European wigeon (*Anas penelope*)	-	-	X
American wigeon (*Anas americana*)	X	X	X
Shoveler (*Anas clypeata*)	-	X	X
Wood duck (*Aix sponsa*)	-	X	X
Ring-necked duck (*Aythya collaris*)	-	-	X
Canvasback (*Aythya valisineria*)	X	X	X
Lesser scaup (*Aythya affinis*)	X	X	X
Barrow's goldeneye (*Bucephala islandica*)	X	X	X
Bufflehead (*Bucephala albeola*)	X	X	X
White-winged scoter (*Melanitta deglandi*)	-	X	-
Surf scoter (*Melanitta perspicillata*)	X	X	-
Ruddy duck (*Oxyura jamaicensis*)	-	X	X
Hooded merganser (*Lophodytes cucullatus*)	X	X	X
Common merganser (*Mergus merganser*)	-	X	X
American coot (*Fulica americana*)	X	X	X

Source: Tabor 1976.

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Table 5-9. Shorebird abundance[a], in their preferred habitats as determined by field studies in the Columbia River basin in the fall (F) and winter (W) of 1973, and the spring (Sp) and summer (S) of 1974.

		River Mile											
		0-12				12-79				79-145			
Species	Preferred Habitat	F	W	Sp	S	F	W	Sp	S	F	W	Sp	S
Semipalmated plover *Charadrius semipalmatus*	mud flats	C	-	C	U	-	-	-	-	-	-	-	-
Snowy plover *Charadrius alexandrinus*	sandy beaches	R	R	R	R	-	-	-	-	-	-	-	-
Killdeer *Charadrius vociferus*	mud flats, beaches	-	U	-	U	R	-	R	R	-	C	-	-
Golden plover *Pluvialis dominica*		Vr	-	-	-	-	-	-	-	-	-	-	-
Black-bellied plover *Plurialis squatarola*	mud flats, beaches	U	U	U	-	-	-	-	-	-	Ac	-	-
Surfbird *Aphriza virgata*	rip-rap	-	U	-	-	-	-	-	-	-	-	-	-
Ruddy turnstone *Arenaria interpres*	mud flats	R	U	-	-	-	-	-	-	-	-	-	-
Black turnstone *Arenaria melanocephala*	rip-rap	-	U	U	-	-	-	-	-	-	-	-	-
Common snipe *Capella gallinago*	marshes	U	U	U	-	C	U	C	-	C	-	-	-
Spotted sandpiper *Actitis macularia*	sandy beaches	-	-	-	-	R	R	-	R	R	R	-	
Solitary sandpiper *Tringa solitaria*	mud flats	R	R	-	-	-	-	-	-	-	-	-	-
Wandering tattler *Heteroscelus incanus*	rip-rap	U	U	-	-	-	-	-	-	-	-	-	-
Greater yellowlegs *Tringa melanoleuca*	mud flats	R	-	-	-	R	-	-	-	U	R	-	-
Red Knot *Calidris canutus*	tidal flats	-	U	-	-	-	-	-	-	-	-	-	-
Pectoral sandpiper *Calidris melanotos*	marshes	R	-	-	-	-	-	-	-	-	-	-	-
Least sandpiper *Calidris minutilla*	mud flats	C	C	-	-	R	-	-	-	R	-	-	-
Dunlin *Calidris alpina*	mud flats	Vc	Ab	Ab	-	Ab	-	-	-	C	C	-	-
Long-billed dowitcher *Limnodromus scalopaceus*	mud flats	-	-	-	-	-	-	-	-	-	U	-	-
Western sandpiper *Calidris mauri*	mud flats, marsh	Vc	C	Vc	U	C	-	Vc	-	C	R	-	-
Sanderling *Calidris alba*	sand beaches	-	U	-	-	C	-	R	-	-	U	-	-
Northern phalarope *Lobipes lobatus*	open water	C	C	-	-	-		-	-	-	-	-	-

[a] Abbreviations are as follows:
Ab = Abundant - 100 or more birds observed/day.
Vc = Very common - 50-99 birds observed/day.
C = Common - 10-49 birds observed/day.
U = Uncommon - 5-9 birds observed/day.
R = Rare - 1-4 birds observed/day.
Vr = Very rare - fewer than 5 birds observed/season.
A = Accidental - 10 or fewer records for a season.
Source: Tabor 1976.

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On the Ridgefield National Wildlife Refuge roughly 1,500 hunter visits occurred from October through January 1979-1980 (Table 5-10). Nonconsumptive uses included waterfowl and shorebird observations for educational and recreational purposes and accounted for approximately 1,200 visits per year. Clearly, total estuarine recreational use would be substantially greater.

Although not a major waterfowl production area, the Columbia River Estuary is an important overwinter resting and staging area, from late summer through spring. The Lewis and Clark, Columbian White-Tailed Deer, and Ridgefield National Wildlife Refuge, in addition to the Sauvie Island Wildlife Management Area are especially noted for their large concentrations of overwintering waterfowl.

Shorebirds, including the phalaropes, snipes, sandpipers, and plovers, use the estuary primarily during migration. They rest and feed along the extensive beach and mudflats before resuming their south- and northwestern movements. Spotted sandpipers, killdeer, and snowy plovers are shorebird species that breed in the estuary.

5.9.3 Population Status

Waterfowl populations and their migration patterns for the Columbia River have been documented by Tabor (1976). Figure 5.5 shows the general seasonal trends for locations at increasing distances from the mouth of the estuary. In Baker and Grays Bay three influx peaks occur. The first and largest is in October, coinciding with the arrival of 4,000 widgeon and 2,400 coots. The second and third peaks coincide with the arrival of canvasbacks (Aythya valisincria), scaups (Aythya afinis), and surf scoters (Melanitta perspicillata).

Waterfowl populations use the lower Columbia River Estuary as a staging area before their northward migration. Between river miles 12 and 79, waterfowl numbers increase steadily from fall to winter, reaching at least 39,000 birds in February. Mallards (Anas platyrhynchos), pintails (Anas acuta), American widgeons (Anas americana), Canada geese (Branta canadensis), and lesser scaups account for most of the February highs. As migration continues north, bird numbers decrease to less than 9,000 birds in March. The greatest number of waterfowl concentrate in the Ridgefield National Wildlife Refuge (river mile 87-93) and in Sturgeon Lake on Sauvie Island Wildlife Management Area (river mile 87-99). Numbers in these two refuges reach 250,000 in December. Birds leave the refuges in January and February for nearby farmlands before continuing north.

Waterfowl production estimates for three USFWS Refuges are listed in Table 5-11. Productivity is low in the estuary region, when compared with the upstream reaches of the Columbia River.

Shorebird numbers and their relative use of the Columbia River downstream from Portland are noted in Table 5-9. Clearly, the greatest diversity and numbers are found near the mouth of the estuary (River Mile 0-12) in Baker and Grays bays. Dunlin and western sandpipers are the only abundant shorebirds observed along the entire lower Columbia River and Estuary. Small flocks of shorebirds use the estuary mostly during fall and spring migrations.

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Table 5-10. Public use (number of monthly participants) in the Ridgefield and Lewis and Clark Refuges in 1979-80.

Refuge Activity	Month Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	All months
Ridgefield													
Hunting (waterfowl)	145	420	619	235	0	0	0	0	0	0	0	0	1,419
Observing (all wildlife)	532	370	490	565	1,320	680	700	933	828	499	505	488	7,910
Education (all wildlife)	870	62	60	30	20	100	946	1,356	0	0	0	570	4,014
Total	1,547	852	1,169	830	1,340	780	1,646	2,289	828	499	505	1,058	13,343
Lewis & Clark													
Hunting (waterfowl)	650	930	800	480	0	0	0	0	0	0	0	0	2,860
Observing (all wildlife)	30	20	10	12	10	10	15	10	20	40	60	40	277
Education (all wildlife)	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	680	950	810	492	10	10	15	10	20	40	60	40	3,137

Source: U.S. Fish and Wildlife Service. 1981.

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Table 5-11. Estimated number of young waterfowl produced in several national wildlife refuges in the Columbia River area, 1974-75.

Species	Lewis & Clark 1974	Lewis & Clark 1975	Columbian White-Tailed Deer 1974	Columbian White-Tailed Deer 1975	Ridgefield RM 87-93 1974	Ridgefield RM 87-93 1975	Total 1974	Total 1975
Canada goose	5	8	6	6	---	---	11	14
Mallard	150	125	40	60	180	140	370	325
Pintail	15	---	---	---	60	55	75	55
Green-winged teal	75	85	50	50	---	10	125	145
Blue-winged/cinnamon teal	45	20	40	40	65	150	150	210
Wood duck	35	35	60	45	90	85	185	165
Common merganser	50	50	75	60	---	4	125	110
American coot	---	---	---	---	80	70	80	70
Totals	385	338	286	273	505	548		

Source: Tabor 1976.

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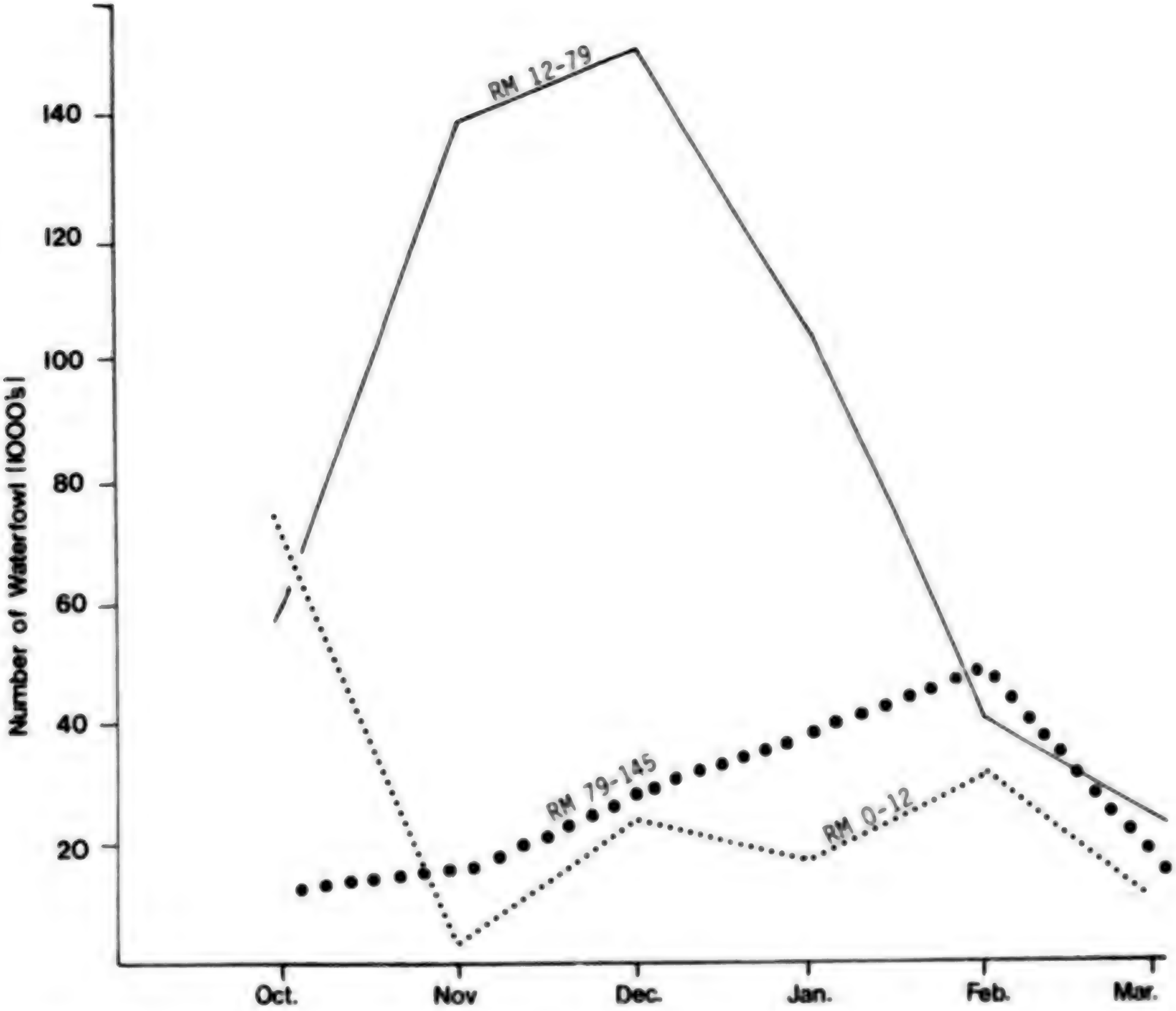

Figure 5.5. Estimated numbers of waterfowl from October 1974 to March 1975 between River Miles 0-12, 12-79, and 79-145 (Tabor 1976).

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5.9.4 Life History

Waterfowl populations are large, and breeding for most species occurs throughout the United States and Canada. Most species exhibit strong propensities for a particular breeding ground and migrate along specific flyways thus resulting in highly localized populations. The availability of year-round food in grain farming areas has enabled Canada geese, mallards, and other waterfowl to remain year-round residents rather than migrants. Association of pairs generally occurs before arrival at breeding areas or soon afterwards. Canada geese are monogamous and pair for life. Among blue-winged teals (*Anas discors*), strong pair bonds are formed prior to incubation. Other waterfowl including mallards and pintail form weak pair bonds. Depending on time of initial nesting, most waterfowl readily renest. Precocial broods of all species have to travel overland before reaching the water, where they are safe from terrestrial predators. Young ducks can generally fly in 34 to 57 days and Canada geese in 49 to 56 days (Bellrose 1980).

Species nesting along the Columbia River downstream from Portland include pied-billed grebe (*Podilymbus podiceps*), Canada geese, mallard, pintail, green-winged teal (*Anas crecca carolinensis*), blue-winged teal, cinnamon teal (*Anas cyanoptera*), wood duck (*Aix sponsa*), and hooded merganser (*Lophodytes cucullatus*) (Tabor 1976). Age of breeding, nesting characteristics, clutch size, and other aspects of the reproductive biology for these and three species of shorebirds are presented in Table 5-12.

5.9.5 Food Habits

Waterfowl vary widely in food preferences; some being strictly herbivorous, others carnivorous, and a third group omnivorous. Canada geese are vegetarians feeding on the foliage of sedges, grasses, the roots and rhizomes of rushes, and the seeds of many aquatic plants. Agricultural cereal grains are also readily consumed. Ducks, however, may be herbivorous or carnivorous. The surface or puddle/dabbling ducks such as American widgeons, mallards, green-winged teal, cinnamon teal and northern shoveler (*Spatula clypeata*) graze on shallow water macrophytes, eating their foliage and seeds. Aquatic invertebrates are also occasionally consumed. Diving ducks or open water bay and sea ducks, such as goldeneyes (*Bucephala islandica*) and buffleheads (*Bucephala albeola*), feed almost exclusively on aquatic animals and insects. Mergansers and grebes feed on fish, and scaup, being opportunistic feeders, take both animals and plants.

Many shorebirds winter along the Columbia River Estuary shoreline and nest in Alaska and Canada. Most are monogamous and precocial, the young foraging with parents almost as soon as they dry off from hatching. Age at sexual maturity is one to two years.

Shorebirds nesting in the Columbia River Estuary include Western sandpiper (*Calidris mauri*), killdeer (*Charadrius vociferus*), and possibly a few snowy plovers (*Charadrius alexandrinus*). As a group, shorebirds nest on the ground, in exposed areas, among shells, pebbles, and pockets of

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Table 5-12. Breeding habits of nesting waterfowl and shorebirds of the Columbia River Estuary.

Species	Age at 1st breeding	Initiation of incubation	Nest site characteristics	Clutch size	Days of incubation	% of nests successful	Average Weight (lbs.) Male	Average Weight (lbs.) Female
Waterfowl								
Canada goose (dusky)	2nd year	early March	wide range upland - water	5	26-28	70	9.9	8.3
Mallard	late 2nd year	April	upland within 100 yards of water	7-10	26-30	46	2.7	2.4
Cinnamon teal	2nd year	mid-April	marsh vegetation	4-16	21-25	51	0.7	0.8
Green-winged teal	2nd year	April	upland dense grass and weeds	5-16	28-34	32	0.7	0.7
Blue-winged teal	2nd year	late April	grassy uplands	6-15	23-27	35	1.0	0.8
Wood duck	2nd year	late March	large trees	10-15	28-37	--	1.5	1.5
Common merganser	3rd year	early May	trees and banks	6-17	34-35	>85	3.6	2.7
American coot	--	--	dead reeds and grasses in marshes	7-16	--	--	--	--
Shorebirds								
Western sandpiper	--	early June	grass-lined scrape near shore	3-5	15	--	--	0.06
Killdeer	--	early April	wide range field and pastures	4	24-28	--	--	0.18
Snowy plover	--	April	shifting dunes	2-4	--	--	--	--

Source: Waterfowl (Bellrose 1980); Shorebirds (Bent 1928); Snowy plover (Wildrig 1979).

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grass. Plovers nest in sparsely vegetated and unstable sand just inland from high-tide lines. In general, shorebird eggs are blotched with dark colors, but overall inconspicuous. The downy chicks are grey to brown with blackish nestlings. Breeding usually occurs in May and June for the first clutches; however, renesting and late clutches may occur in some species. The breeding habits of the nesters known to occur in the estuary are presented in Table 5-12.

Shorebirds feed on aquatic invertebrates such as mollusks, crustaceans, worms, and insects found in the moist sand and mud. Frequently, they feed along the driftline and look for small invertebrates among emergent vegetation. The snowy plover feeds on flies, worms, sandfleas, beach hoppers, and other small invertebrates along sandy shores (Eaton 1975). Occasionally they also eat plant material.

5.9.6 Factors Affecting Distribution and Abundance

5.9.6.1 Natural factors. The limited area of nontidal marsh is thought to be the reason for the low density of breeding waterfowl in the lower Columbia River Estuary (Tabor 1976). Swans, geese, and ducks require a mixture of wetland, riparian, and upland sites, sufficiently protected from mammalian and avian predators; this is unavailable along most of the lower reaches with the exception of some of the wildlife refuges. Availability of good breeding grounds has been found to relate to the proportion of yearlings breeding in numerous waterfowl populations (Bellrose 1980). Sheltered water for feeding, resting, and sleeping are important to grebes and many bay and open water ducks such as mergansers and goldeneyes. Calm waters in protected bays, behind breakwaters, or on leeward side of islands are traditional concentration areas.

Immature ducks have a first-year mortality rate of 60 to 70 percent and a subsequent yearly rate loss of 35 to 45 percent (Bellrose 1980). Greater hunting losses among the immatures account for most of the differences in mortality rates between the two age classes. Approximately one half of annual mortality is attributable to hunting (Bellrose 1980).

Substantial numbers die of disease or are eliminated by predation. Well-known diseases of waterfowl which frequently reach epidemic proportions are botulism, fowl cholera, duck virus enteristis, and lead poisoning (Bellrose 1980). Leucocytozoinois and sarcosporidosis are diseases of lesser importance in the northwest (Brewer, Washington State Game Dept.; pers. comm.). Aspergillosis, however, is common and caused by foraging in contaminated waters.

Suitable breeding and nesting habitat is thought to be the most important limiting factor for many shorebirds (Marshall 1969; Pinto et al. 1972; Eaton 1975). Because large tracts of suitable habitat still remain within the estuary, human activity may be important. This apparently is the case with the snowy plover.

Little information is available on the causes of mortality in shorebirds; winter storms are probably an important factor for migrating shorebirds, especially for newly fledged birds. Late spring storms and concomitant high tides may also be important in destroying nests and young. Some predation by falcons also occurs.

5.9.6.2 Human factors. Tabor (1976) indicated that unstable water levels (in conjunction with limited space) are primarily responsible for the low density of breeding waterfowl in the lower Columbia River and Estuary. For snowy plovers and probably other shorebirds, the human use of dunes for housing and recreation has depleted breeding habitat over portions of the range. Stabilization of dunes by European beach grass (Ammophila arenaria) and by other techniques have further depleted suitable nesting habitats of the plover and other shorebirds that require unvegetated beaches in which to nest and feed (Eaton 1975; Wildrig 1979, 1980, 1981).

Oil pollution poses a periodic severe hazard to water fowl and shorebirds. Bay and diving ducks and shorebirds are especially susceptible.

Hunting of waterfowl directly and indirectly impacts populations, indirect impacts occurring from lead poisioning. A conservative estimate (Bellrose 1980) indicated, "that 2 to 3 percent of the fall and winter waterfowl populations fall victim to lead poisoning each year."

Of mixed benefit to the distribution and abundance of waterfowl is the agricultural industry. Breeding and nesting habitat is reduced by draining wetlands, while cereal and other food crop production provides food for some species.

5.10 GREAT BLUE HERON

5.10.1 Introduction and Description

The great blue heron (Ardea herodias) is a distinctive, large, blue-gray wading bird approximately 120 cm (50 inches) tall with a wing spread of 107 to 132 cm (42 to 52 inches) (Udvardy 1977). It may be mistaken for a sandhill crane (Grus canadensis) but the great blue heron is a resident throughout the estuary, whereas the crane is a migrant restricted to the Suavie Island (river mile 91-102) in the upper reaches of the Columbia Estuary. The great blue heron is also slimmer and lighter bodied and flies with a folded neck.

5.10.2 Resource Value and Estuary Usage

Great blue herons along the Columbia River Estuary are probably year-round residents, moving between habitats up and down the river. Of Baker Bay, Youngs Bay, Grays Bay, and the upriver island area, the greatest average number of great blue herons sighted occurred in Baker Bay (Jones & Stokes Associates, Inc. 1980). During spring, herons were observed only in marsh habitats and the mud flats of Grays Bay. In the summer, they were also observed on mud flats and open areas (pilings, docks, etc.) in Baker Bay and Youngs Bay as well, but not within the upstream island area (Jones and Stokes, Inc. 1980). These observations suggest a limited seasonal migration by residents along the estuary.

5.10.3 Population Status

Great blue heron breeding colonies in the Columbia River Estuary are large and numerous (Table 5-13). Based on fledgling success, western Oregon populations are considered stable (Henny 1971). The sizes and number of colonies suggest that the lower river and estuary are a significant breeding and feeding area for this species. Nevertheless, a nationwide concern about heron population status exists; the great blue heron has been bluelisted by Arbib (1979).

Long range migratory movements of great blue herons are not well known. Band recoveries indicate that some Oregon and Washington birds winter in the Sacramento Valley, California. These birds, however, are probably eastern Washington birds. Extended freezes east of the Cascades drive populations south to California (Gabrielson and Jewett 1940; Jewett et al. 1953).

Diel movements also occur; birds fly from roosts or breeding colonies to feeding sites along the river and mudflats. Nest and roost sites are typically within 16 km (10 mi) of feeding areas (McMahon et al. 1974).

5.10.4 Life History

Great blue herons are communal breeders. They characteristically build large stick nests with as many as 5 to 8 nests in the same tree. Nests may be found in Sitka spruce and red alder, but on the Columbia River Estuary most are in large old-growth black cottonwood trees (Peters et al. 1978). The number of active nests may be related to the size of the nearest estuary and the average tree height (Werschkul et al. 1977). The ratio of active to total nests may be quite variable (Table 5-14).

Three to seven blueish green eggs are laid, hatching in approximately 27 days (Bent 1926; Palmer 1962). Egg laying, incubation, and age status of chicks in the lower Columbia River Estuary colony indicate that the three-month period from April through June is the breeding season. Arrival time at the Karlson Island Colony was reported to be mid-February. Hatching peaks in early to mid-April, and fledging occurs at the beginning of July (McMahon et al. 1974).

Young are typically fledged at eight weeks. The number of fledglings per nest have been recorded within the estuary and the Columbia River Basin. In a case study at Karlson Island (river mile 26), McMahon et al. (1974) and Werschkul et al. (1977) reported a high fledging success of 2.7 birds per nest. Peters et al. (1978) reported fledging rates of 2.17 to 2.71 young per nest for colonies along the Willamette River. McMahon et al. (1974) indicated an average fledging success of 2.3 young per nest for 13 colonies along the Oregon coast. Typical fledging success rates in the west vary from 1.9 (Pratt 1972) to 2.6 (Henny and Bethers 1971). The number of active nests per acre and the average number of nests per tree in

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Table 5-13. Location of heronries of the Columbia River Estuary and adjacent areas.

Geographic name	Source	River mile	Habitat type	Number of pairs
Karlson Island	(McMahon et al.1974) (Nehls 1972) (Werschkl et al. 1977)	26	tidal Sitka spruce	175
Welch Island	(Nehls 1972)	34	black cottonwood	28
Ryan Island	(Peters et al. 1978)	38	stands of large mature black cottonwoods	100
Fisher Island	(Peters et al. 1978)		stands of large mature black cottonwoods	140-300
Sandy Island (North end)	(Tabor 1976)	75	stands of large mature black cotton-	Present but not counted
Deer Island (North end)	(Nehls 1972)	77	stands of large mature black cottonwoods	40
Bachelor Island	(Tabor 1976)	88-91	stands of willows/large mature black cottonwoods	555

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Table 5-14. The location and number of great blue heron nests counted in the spring and summer of 1980 in the Columbia River Estuary.

Location	Date	Number	Number active	Status of nests
Ryan Island	18 March	33-37	12	Laying/incubating
	1 April	36	9-12	Incubating/brooding
	8 May	-	-	Young well developed
Brown's Island	24 April	52	40	Young present
	8 May	-	-	Young present
Karlson Island	-			Active - no data
Welch Island	-			Inactive - no nests
Brown's Creek	27 June	10	-	Young mostly fledged
Clatsop Ridge	27 June	31	-	Young nearly fledged

Source: Jones and Stokes Associates, Inc. (1980).

a heronry significantly related to colony success in a study by Werschkul et al. (1977).

Great blue herons arrive in the Columbia River Estuary in early February (Werschkul et al. 1977). Young are fledged in 8 weeks and exhibit sustained flights at 9 weeks. Young stay in the vicinity of the nest and are fed until they are 11 or 12 weeks old (Pratt 1972). Departure from the nest area occurs in approximately 12 weeks (Palmer 1962; Pratt 1972). Young attain adult size by the first winter, but do not become sexually mature until their second year.

5.10.5 Food Habits

Great blue herons typically feed in open wetlands, intertidal marshes, mud and sand flats, diked estuarine marshes, riparian areas, and grasslands. Their preferred feeding habitats in the Columbia River Estuary are intertidal mudflats (McMahon et al. 1974).

Adults typically feed on small fish and other aquatic animals. Their diet varies considerably depending on local food availability. For example, they feed on small mammals when abundant (Krebs 1974), but most of their diet is usually fish.

In a nationwide summary of 189 great blue heron food habit studies, about 43 percent of their diet was found to be nonsport and noncommercial fish, 25 percent sport or commercial fish, 8 percent insects, 8 percent crustaceans, 5 percent mice and shrews, and 4 percent reptiles and amphibians. Estuarine birds would likely have a greater proportion of crustaceans and fish and a smaller proportion of reptiles, amphibians, and insects in their diet. Food items vary seasonally and annually, depending on the relative availability of prey species. The behavioral adaptations to catch respective food has been described by Kushlan (1976).

5.10.6 Factors Affecting Distribution and Abundance

5.10.6.1 Natural factors. Great blue heron young experience substantial mortality prior to fledging; typically, 40 to 50 percent of the original clutch is unsuccessful (McMahon et al. 1974). A major cause of mortality is the asynchronous hatching over a 5 to 8 day period, which gives the larger, older chicks a competitive edge at the nest; younger birds may starve or be pecked to death by older chicks (McMahon et al. 1974). Fledging success is further reduced by hatching failures, weather, predation, parasites, and disease.

Once great blue herons have acquired full growth they have few natural enemies (Eckert and Karalus 1981). Natural adult mortality for herons within the Columbia River Estuary has not been thoroughly investigated.

5.10.6.2 Human factors. Great blue heron populations in the Columbia River Estuary appear to be stable, but long-term data are not yet available for determining human impact. Great blue herons are at the apex of aquatic food webs; thus, they are susceptible to bioaccumulation of toxins. Toxins (e.g. dieldrin, DDT and derivatives, PCBs) are released in large quantities upstream of the Columbia River Estuary and may be transported to the estuary where they could harm resident populations. Radionuclides have been observed in feces from heron feeding in waste ponds up to 24 km (15 mi) from the source (Rickard et al. 1978).

In a study of green and little blue heron rookeries in a pond contaminated with radiocesium, Domby et al. (1977) found that green herons that fed outside the contaminated area were unaffected and that little blue herons that fed in the pond acquired one third the concentrations displayed in their prey base. Heron eggs are sensitive to being exposed to hydrocarbons. White et al. (1979) applied No. 2 fuel oil to naturally incubated Louisiana heron eggs, causing 61 percent mortality after five days.

Before the 1960's, great blue herons were commonly shot because they were believed to prey on game and commercial fish. The great blue heron is now protected by state and Federal legislation. Nevertheless, it is a large, obtrusive bird that is still frequently killed by thoughtless hunters. For example, McMahon et al. (1974) reports finding 13 young and three adults shot at a heronry in Oregon.

Collision with transmission lines also is a human related mortality factor. Thompson (1978) reports that members of the order Ciconiiformes readily collided with transmission lines of various types, probably because of their large size and low flying altitude. A review of banding returns for great blue herons in the Sacramento Valley indicated that 2 out of 13 recoveries were associated with possible wire strikes.

Heron mortality due to wire strikes is reported by Lee (1978) and Willard et al. (1977), and in the upper Columbia River, by Rickard et al. (1978). In two detailed studies by Wiese (1976, 1977) in Delaware, no wire strike mortalities were recorded for 500-kV utility lines near a major heron, egret, and ibis rookery. The birds avoided wires by flying over or under the obstacle, and during poor weather either flew near the water surface or remained on the island. Apparently, the number and severity of collisions depend on the proximity of nesting and roosting areas to powerlines, the age of birds, and weather factors.

Human activities near heronries often interfere with reproduction or result in desertion by the birds. McMahon et al. (1974) report the following:

> "In five areas (heronries) which showed no signs of past or recent disturbance 92 to 97.8 percent of the nests contained breeding pairs. Three areas with nest activity of 61, 64, and 78 percent showed evidence of obvious disturbance. The heronry with 61 percent activity had a logging road constructed within 80 feet of the nests, logging nearby during the breeding season, and three adults shot at the nests. The heronries with 64 percent and 78 percent activity had clearcutting within 100 yards in the last 10 years which made the surrounding trees susceptible to blow down, and exposed the trees with nests."

Even when buffer zones surround a heronry, habitat loss is possible. As an example, the Old Ball Mountain heronry was abandoned after clearcutting the area, even though a 3.2 ha (8 acre) buffer was left. The clearcutting altered wind patterns and blew down many roost trees. The colony was subsequently deserted (McMahon et al. 1974).

Werschkul et al. (1976) reported an inverse relationship between human disturbance and nest density and occupancy at Oregon heronries.

On the other hand, herons have shown a capacity for accepting long-term disturbances. For example, a highway was built 244 m (800 ft) from the Indian Island Rookery without causing any apparent desertion (Schlorff, California Fish and Game; pers. comm.). Similarly, in Coos Bay, Oregon, a rookery near the end of an airport runway did not seem to be affected by the disturbance.

The tenacity of herons to a colony site may depend upon productivity of an area, habitat, and colony condition.

Herons often adapt surprisingly well to man-made structures. Henny and Kurtz (1978) found great blue herons nesting on channel markers along the Columbia River near Umatilla, Oregon. Along the Columbia Estuary, herons often use log rafts for loafing (Peters et al. 1978). Also, numerous dredge spoil areas have potentially increased feeding habitat for this species.

5.11 WESTERN AND GLAUCOUS-WINGED GULLS

5.11.1 Introduction and Description

Gulls are usually the most apparent and abundant waterbirds in the coastal areas and the Columbia River Estuary. They frequent estuaries and rivers and fly inland to feed. Numerically, the most dominant gulls are the western (*Larus occidentalis*) and glaucous-winged gulls (*Larus glaucescens*).

These two species hybridize along the Oregon and Washington coast (Hoffman et al. 1978). The two gulls differ significantly in plumage; wing and back coloration is black to grey in western gulls and pale grayish-white in glaucous-winged gulls. Mantle shading varies significantly and ranges from a dark bluish-gray in western gulls to a light gray in glaucous-winged gulls. Hybrids exhibit all intergrades of wing and mantle coloration.

Mature glaucous-winged gulls are larger than western gulls, weighing 1,010 g (35.6 oz) as opposed to 980 g (35.4 oz). They also have a larger body size of 12 cm (4.7 inches) and 8 cm (3.1 inches) longer wing span.

5.11.2 Resource Value and Estuary Usage

A single large colony of western, glaucous-winged, and hybrid gulls breed on East Sand Island in Baker Bay near the mouth of the Columbia River Estuary. These gulls inhabit the Island from late March through late August, when most birds migrate south. Breeding and nonbreeding gulls loaf along large stretches of sandy beach. They are opportunistic and feed on a variety of foods within Baker Bay and throughout the Columbia River Estuary. Quantifying the resource value of these birds is difficult. Fundamentally, they provide a valuable esthetic resource to bird watchers and photographers. In addition, they are a valuable ecological and scientific resource and may also represent good biological indicators, reflecting the health of the environment. Certainly, they are an important scavenger.

5.11.3 Population and Status

The ecology of the only large colony of breeding gulls in the Columbia River Estuary has been extensively studied by Richter (in prep.). A total of 832 occupied nests were counted in early June 1981 in East Sand Island, suggesting a breeding population of at least 1,664 gulls (Table 5-15) (Richter in prep.). Assuming that some nests were overlooked and that a few gulls nest after early June, roughly 1,700 adult birds use the island and the surrounding estuary. This number is significantly higher than the 1,200 breeding birds estimated from partial habitat sampling in 1977 by Peters et al. (1978) and the 1,306 pairs extrapoloated from transect counts

Table 5-15. Number of nesting western and glaucous-winged gulls in different habitats on East Sand Island on June 4, 1981.

Habitat	Number of nesting gulls
Beach	172
Storm plain	244
Grass-herb meadows	142
Dune	268
Revetment	838
TOTAL	1,664

for 1980 by Jones and Stokes ornithologists (Envirosphere 1981), suggesting that the colony is rapidly expanding.

Besides adult gulls, a large flock of approximately 300 nonbreeding gulls spend the summer adjacent to the colony at the east end of the island.

Both adults and young remain at East Sand Island throughout the breeding season, from late March through late August, at which time adults, immature, and newly fledged young disperse. Resightings of chicks banded by Richter in 1978-1980 show that, as juveniles, some migrate north to British Columbia, although most gulls fly south and spend the winter along the Oregon and California coast. San Francisco Bay appears to be a favorite overwintering area since the greatest number of banded birds were observed there (Richter in prep.). Some birds were observed using the southern California coast in the vicinity of Ventura. In general, the extent of southward migration and time of reappearance at the breeding colony in spring appears to be related to weather.

5.11.4 Life History

Gulls pair for life, return to natal colonies for breeding, and often use the same nest site for many years. This behavior results in a degree of breeding isolation between colonies.

Studies by Richter (in prep.) indicates that the two gull species tend to nest in different habitats. Western gulls typically nest in beach and revetment habitat types, and to a lesser degree, in grass-herb meadows and storm plains types. Glaucous-winged gulls, however, nest in greater numbers in grass-herb meadows and less in revetment and beach areas. Hybrid gulls were generally observed in low densities in all habitats. Counts of nesting pairs of western and glaucous-winged gulls indicate that gulls mate with members of their own species in all habitats except the storm plain, where mating between the two species apparently is random (Richter in prep.).

Gulls arrive in March, and by the first of April, many occupy established territories on the revetment and meadows. By late April more than 80 percent of the season's nests are completed. Copulation occurs during the early breeding season, and nest construction and egg laying soon follows. Clutch size average from 2.8 to 3.0 eggs per nest. In glaucous winged gulls the sexes share equally in incubation (Vermeer 1963), whereas for the western gulls, females are most frequently observed incubating eggs (Pierotti 1975).

In the mixed colony in East Sand Island, gulls share incubation (Richter in prep.). Both members of a pair aggressively defend a nest site prior to and during egg laying and chick development. Territorial boundaries are stable during nesting, but become less rigid as chicks hatch and become increasingly mobile. Egg laying begins during the second week in April and continues through the fourth week in June. Peak incubation occurs in the third and fourth weeks of April. Peak incubation dates for successive clutches follow at 3.5 week intervals.

Preliminary estimates of more than 100 nests indicate that the number of chicks surviving to fledge in the East Sand Island colony is roughly 1.5 gulls per nest, being lower for beach and higher for revetment nesting birds. This value is lower than the 1.7 gull per nest average (353 nests in a 2 year period) observed for glaucous-winged gulls in Glacier Bay Alaska (Patten 1974), but similar to the 1.0 to 1.7 glaucous-winged gull chicks per nest (97 nests in 1961 and 479 in 1962) observed by Vermeer (1963) on Mandarte Island, British Columbia.

Density values for nests of western and glaucous-winged gulls range from 2.4 to 6.4/100m^2 (0.06 to 0.16/acre) in beach and grass-herb habitats, respectively (Table 5-16). Beach and storm-plain habitat types have the highest nest densities, indicating preference for these types. Nest density within habitat types was highest adjacent to logs, rocks, and other obstructions (Richter and Peters 1978).

Incubation does not start until the clutch is complete and varies between 25 to 29 days. Newly hatched chicks weigh a mean of 73.5 g (2.6 oz), and at one week average 322 g (11.3 oz) (Patten 1974), thus more than trebling their weight in seven days. Chicks can swim approximately four weeks after hatching. They aggregate into small groups, but separate to be fed by parents. Frequently, they return to shore to be fed by adults on land. The length of the fledging period, when gulls become independent of adults, is between 40-50 days, and some young gulls are observed at nearby islands and mainland at the end of August.

A few immature gulls may be seen at the breeding colony within three years carrying nest material; however, first breeding in substantial numbers does not occur until the fourth year (Vermeer 1963).

Table 5-16. Number and density of nests (number/100 m^2) of western and glaucous-winged gulls on June 4, 1981.

Habitat	Area of habitat type (m^2)	% of total study area	Number of nests	% of total nests	Nests/ 100 m^2	Rank[a]
Beach	450	15	29	24	6.4	1
Storm plain	750	24	37	30	4.9	2
Grass herb meadow	931	30	23	19	2.4	5
Dune	610	20	17	14	2.8	4
Revetment	330	11	16	13	4.8	3
Total	3071	100	122	100	4.3	

[a] In decreasing order.

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The average life span of a glaucous-winged gull (and probably western gull as well) is estimated at 13.5 years (Vermeer 1963). This estimate assumes four years to mature and a life expectancy of first breeding adults at 9.5 years. Glaucous-winged gulls in the wild may live to be at least 21 years as established by banding, but black-backed gulls have been reputed to live up to 64 years in captivity (Vermeer 1963), indicating that the potential for life beyond 13.5 years is significantly greater.

Counts of 289 birds in 1979 indicate that western, glaucous-winged, and hybrid gulls represented 48, 26, and 26 percent, respectively, of the nesting population of East Sand Island. These values do not differ significantly from a mid-1970 island survey of 16 birds in which 44, 25, and 31 percent were western, glaucous-winged, and hybrid gulls, respectively (Hoffman et al. 1978).

5.11.5 Food Habits

The breeding gulls on East Sand Island eat fish and shellfish as determined from food at nest sites and from manually regurgitating recently fed chicks. Small fish included surf smelt, Pacific herring, and sculpin. Also found were goose neck barnacles and several small clams and crabs (Richter in prep.). Refuse was not observed at nest sites and most likely does not constitute any significant dietary component of chicks or adults during the spring and summer. In fall and winter, however, yearlings have been observed feeding at refuse dumps along the Pacific Northwest and California coasts (Spear, Point Reyes Bird Observatory; pers. comm.).

5.11.6 Factors Affecting Distribution and Abundance

5.11.6.1 Natural factors. The primary limiting factor for continued recruitment of glaucous-winged and western gulls on East Sand Island is the availability of optimum nest sites which, on this island are habitats exhibiting abundant cover to protect adults and young from weather and young from attack by adults (Richter in prep.). Intraspecific predation by adults on other gull's young results when nests are too densely spaced in habitats (beach, dune, and grass-herb) in which protection from wandering adult gulls from neighboring territories is unavailable.

Although potential nesting habitat still remains unoccupied in the central and eastern half of the island, the nucleus of the colony remains at the west end. It is in the center that gulls are most successful (Richter in prep.), since habitat characteristics, bird density, and bird ages are optimum. Gull populations have not changed on the west side of the island since 1977. Rather, breeding birds have slowly extended the colony toward the center and eastern end of the island, especially along the revetment and grass-herb meadows. Although these habitats support birds, the rate of success is expected to be low because immature birds in too low a density at the periphery of the colony are not as successful as those within the main colony.

The May 1980 Mt. St. Helens eruption covered the usually populated western beach with logging debris, forcing beach nesting gulls to relocate on the previously unoccupied north-east beach. This demonstration of gull mobility with respect to nesting sites further suggests that the island's habitats are able to support additional breeding gulls.

A small number of chicks may die from exposure to cold and rainy weather. This mortality is greatest in beach and grass-herb meadow nest sites and among gulls with poor nest attendance.

Late spring high tides can wash nests away, and winds occasionally bury nests. The low elevation of the breeding colony also makes it prone to tsunamis and storm surges.

Since no starvation was observed and the only dead birds had died of gunshot and fishing gear, food and physiological factors appear not to have a significant influence on the dynamics of this colony. However, the extent to which these factors could influence the colony in the future remains undetermined. In general, the colony is healthy and recruitment is above average and should stay so as long as the island remains isolated, inaccessible, and undisturbed by humans.

Major avian predators on gulls are bald eagles, great-horned owls (Bubo virginianus), red-tailed hawks (Buteo jamaicensis), and crows (Corvus brachyrhynchos), none of which have been directly observed preying on the East Sand Island gull colony during four field seasons. Mammalian predators include rats, raccoons (Procyon lotor), and other egg eating species, none of which were observed on the island in the summers of 1977 through 1980 (Richter in prep.).

5.11.6.2 Human factors. Adult gulls are noted for their tolerance of human activities and are attracted to garbage dumps, fish processing plants, and agricultural fields. Nevertheless, human activities, foremost among which are dredging, tanker commerce, industrial developments, use of pesticides and herbicides, recreational pressure, and vandalism, can sometimes be detrimental to gulls and their breeding colonies.

The most direct disturbance to the gulls of East Sand Island is that associated with dredging of navigation channels in Baker Bay. As recently as 1978, the channel to Chinook boat harbor was dredged and spoils dumped at the east third of the island, resulting in some gull habitat loss. The impact, however, could have been more damaging if spoil slurry was pumped further west onto the active colony, or if the holding dikes collapsed, resulting in flooding of adjacent nesting territories. More subtle, but possibly equally adverse, could be the noise associated with on- and off-shore dredging. During critical nesting periods, noise causes physiological and behavioral changes in incubating adults, leading to reduced viability, nest desertion, and total colony abandonment (Buckley and Buckley 1978).

The increase in tanker traffic, oil storage farms, refining facilities, and other pretroleum related activities represent another threat to the breeding gulls. Singly, or in combination, these activities will likely result in higher chronic exposures of petroleum hydrocarbons to gulls and to the marine life (shellfish, fish, and molluscs) they eat. The extent of food web magnification of oil is presently unclear. Seemingly healthy herring gulls collected in oil spill areas concentrate large quantities, 584 ppm and 535 ppm (control gulls have 10 and 15 ppm) in muscle and brain tissue (Burns and Teal 1971), respectively. Concentrations also occur in body fat (Fox et al. 1975). Biological effects of chronic oil ingestion could include adverse effects on physiology, especially aspects of reproduction and behavior.

Sublethal levels of oil on the plumage of birds leads to serious egg mortality when adults incubate. Decreases in hatchability of oil smeared eggs have been documented by Rittinghaus (1956) and Hartung (1965). Recently, preliminary results by Patten and Patten (1977a,b) indicated that field exposure of 20 to 100 microliters of North Slope Crude Oil to eggs of both glaucous-winged and herring gulls during early stages of incubation leads to high embryo mortality.

Mercury originating from fungicides used to protect grain and seeds have been shown to concentrate in herring and ring-billed gull eggs (Vermeer 1971) and cause hatching failure in some eggs. Toxicity from other pesticides may also lead to sick adults and reduced viability in eggs. A general discussion of the exposure of marine birds to environmental pollutants is provided by Ohlendorf et al. (1978).

Dredged materials, which are disposed on spoil islands, frequently contain high concentrations of toxins which have accumulated over the years.

Pesticide runoff from agricultural fields and contaminated crops pose a potential threat. The effects of DDT on bird productivity are well known; the effects of PCB's are currently under investigation. Evidence is substantial that organochlorides in general are detrimental to marine birds and their reproduction.

With increasing development along the Columbia River Estuary, disturbances by aircraft, recreationists, and others could increase and disrupt breeding at this gull colony. As the number of visitors to the island increase, chances of predation by native or non-native animals also increases. Feral cats and dogs can obliterate an entire colony in a short time. Likewise, the unintentional introduction of rats on this island could be detrimental.

Occasional vandalism occurs on the island. In 1977, some boys were observed throwing rocks at nesting gulls. In April of 1980, gulls were shot; four were found dead, or dying, on the beach and at the periphery of the colony.

In summary, there are several water related activities along the Columbia River Estuary that exhibit the potential to impact the East Sand Island gull colony. At present, the remoteness of this island has protected the gulls from human influences; however, the effect from increased river use remain to be determined.

5.12 BALD EAGLE

5.12.1 Introduction and Description

The bald eagle (Haliaectus leucocephalus) has an extensive range encompassing the North American continent. The USFWS classifies this species as threatened in five states, including Oregon and Washington, and as endangered in 43 other states. The species has been divided into two subspecies, the southern bald eagle (H. l. leucocephalus) and the northern bald eagle (H. l. alascenusis) (AOU 1957).

The northern bald eagle occurs along the Columbia River and breeds from the Aleutians, Mackenzie, Ontario, Quebec, and Newfoundland south across the northern half of the conterminous United States (AOU 1957). This subspecies is larger and heavier than its southern counterpart, females of both subspecies being larger than males. The head and tail of the adult bald eagle is distinctively white. Juvenile eagles, however, lack this plumage and are often confused with golden eagles (Aquila chrysaetos).

5.12.2 Resource Value and Estuary Usage

The southern subspecies was listed as endangered in 1967; however, the northern subspecies, because of its large Alaskan population, was not classified until the enactment of the Endangered Species Act in 1973. All populations of the northern subspecies outside of Alaska have been classified as either threatened or endangered since 1978 (USFWS 1978c).

Bald eagles are known to breed (Eaton 1975), winter (Opp 1980), and migrate through the vicinity of the lower Columbia River. The greatest density of eagles in this region generally occurs during the fall and winter months.

5.12.3 Population Status

According to literature surveys by the U.S. Army Corps of Engineers (1979), and field surveys conducted by the U.S. Fish and Wildlife Service in 1973 and 1974 (USFWS 1974), approximately 1,000 pairs of bald eagles nest in the conterminous United States (USFWS 1974); nonbreeding adults and immatures probably account for another 500 to 1,000 birds (Marshall and Nickerson 1976). Alaska supports the largest known population of northern bald eagles, estimated between 30,000 and 55,000 birds (USFWS 1974). Significant numbers of breeding eagles occur southward along the Pacific Coast to the Olympic Peninsula in Washington. An estimated 1,000 nesting territories exist on Vancouver Island and adjacent islands off the British Columbia-Washington coast (Hancock 1965).

Populations of bald eagles are believed to have increased in Washington since 1971 (Eaton 1975). Most bald eagles breed west of the Cascades, primarily along the Washington coast, Puget Sound, and the Olympic Peninsula. Reichard (1976) reported 20 active nests along the Washington Coastal Zone, and Thompson and Snow (1974) reported 16 eagle nest sites for the Oregon Coastal Zone. An intensive survey conducted in 1974 and 1975 found 114 active nests in western Washington, the largest population in the conterminous states (Grubb 1976). Bald eagle nesting attempts along the lower Columbia River were observed at 4 of 12 nests in 1977 and 6 of 12 in 1980 (Isaacs and Anthony 1981). Successful active nests from which young were fledged, however, dropped from 3 to none. Clearly, there is cause for concern regarding the bald eagle population within the Columbia River Estuary.

Minimum counts of wintering bald eagles in Washington for 1979 and 1980 are depicted in Tables 5-17 and 5-18. Although a significant increase in the number of eagles counted is evident, this increase is probably due to the combination of more intensive surveys and better survey methods (Knight, Washington Dept. of Game; pers. comm.). Although most of the eagles were observed in the Puget Trough and along the western slopes of the Cascades, many were observed in southwestern Washington.

Bald eagle counts in Oregon indicate that the largest wintering population found in the lower 48 contiguous states, numbering over 600 birds, occurs in the Klamath Basin (Opp 1980). Other major wintering areas include the Skagit, Nooksack, Squamish, Fraser, lower Columbia, and Snake rivers and their major tributaries, the San Juan Islands in northern Puget Sound, the Skagit-Samish flats, and the marsh areas in southeastern Oregon.

Migration patterns for bald eagles are variable, depending on point of origin. The northern bald eagle appears to have a highly developed migratory pattern, in which the most northerly breeding populations tend to overfly and winter further south than the more southerly populations (Brown and Amadon 1968). In coastal areas where climate is moderate, breeding populations may be resident year-round (Sherrod et al. 1974). In Washington, resident eagles breed and winter in areas along the Pacific coast, Olympic Peninsula, San Juan Islands, and major northwest drainages (Grubb 1976; Hunt et al. 1980; Knight et al. 1980). Major wintering areas are found on rivers with substantial salmon runs, such as the Skagit (Servheen 1975; Hunt et al. 1980), Nooksack (Stalmaster 1976), and Skykomish (Hansen and Bartelme 1980). Lesser concentrations occur on estuaries and rocky shores, including Grays Harbor, Williapa Bay, and Grenville Point. Wintering eagles in the Klamath basin are suspected to migrate and breed in British Columbia and Saskatchewan (Opp 1980). Servheen and English (1979) and Hunt et al. (1980) used patagial marking and biotelemetry to document coastal and continental migratory routes for Alaskan and Canadian bald eagles entering southern British Columbia and northwest Washington to winter.

5.12.4 Life History

Bald eagles do not become sexually mature until their fifth or sixth year (Brown and Amadon 1968). Clutches vary from one to four eggs; most commonly two eggs are laid (Brown and Amadon 1968). Although attainment of adult plumage signals sexual maturity, several observers report nesting by immatures (Hoxie 1910; Bent 1937; Murrie 1959; Kalmbach et al. 1964; Sherrod et al. 1976; all cited in US Army Corps of Engineers 1979). An early loss of the first clutch may result in a second within a month

Table 5-17. Estimated number of wintering bald eagles in different physiographic provinces in Washington between 13-27 January 1979.

		Area surveyed		Bald eagles			
Physiographic province	Number of observers	Miles	Miles^2	Adult	Immature	Unknown	Total eagles
Olympic Province and southeastern Washington	57	525	17	68	55	5	128
Puget Trough	113	845	352	199	196	19	414
Western slopes and crest of Cascades	20	177	1	241	195	10	446
Eastern slopes of Cascades	9	271	46	11	3	--	14
Okanogan Highlands	6	319	--	6	--	--	6
Columbia Basin	27	380	19	68	50	--	118
Blue Mountain	--	--	--	--	--	--	--
Total	232	--	--	593	499	34	1126

Source: Orlins 1979.

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Table 5-18. Estimated number (minimum count) of wintering bald eagles in different physiographic provinces in Washington, January 2-20, 1980.

Physiographic province	Number of observers	Area surveyed		Bald eagles			
		Miles	Miles^2	Adult	Immature	Unknown	Total
Olympic Province and southeastern Washington	70	393	309.25	176	69	1	246
Puget Trough	197	924.7	900.5	266	210	--	476
Western slopes and crest of Cascades	30	561	--	335	292	--	627
Eastern slopes of Cascades	38	869	37	39	24	--	63
Okanogan Highlands	18	598	43	37	13	--	50
Columbia Basin	53	834	106	94	63	--	157
Blue Mountain	1	10	--	5	--	--	5
Total	407	4189.7	1395.75	952	671	1	1624

Source: Knight et al. 1980.

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(Herrick 1934; Bent 1937). Nesting usually begins in early February, and young fledge in July (Reichard 1976). Assuming an incubation period of about 35 to 40 days (Snow 1973; Brown 1977) and a nesting period of about 75 days (Howard and Van Daele 1980), a minimum of 110 days is required at nest sites from laying to fledging. Eagles are unable to feed themselves until approximately seven weeks old. Fratricide is known to occur during this period, although its influence on productivity is not clear (Snow 1973). It seems logical that the occurrence of fraticide may be induced by low food availability.

The majority of nests are built in large trees along marine coastlines, usually within 180 m (600 feet) of the shore (Reichard 1976). Discriminant analysis of common nest parameters related to activity and success at eagle nests in the San Juans Islands suggests that land ownership (private versus public such as wildlife refuges, Indian reservations, National Forests, etc.), forest stand characteristics, nest tree characteristics, absence of human activity, and weather are the most important factors (Grubb 1980). Additionally, Grubb (1980) found that human disturbance was the greatest adverse impact, and that poor weather also decreased nest productivity. The U.S. Army Corps of Engineers' (1979) literature survey stated:

> "The optimum nesting environment of the northern bald eagle is probably a shoreline habitat which provides ample food; tall trees for nesting, hunting, and loafing perches; and open flight paths on updrafts in an area which is sparsely populated by humans (Whitfield et al. 1974). Proximity to open water is the prime factor determining the selection of a nest site. Food availability is the reason for this preference, as fish comprise a major portion of the diet of nesting bald eagles and their young. Particularly during the first few weeks following hatching, food must be obtained in a minimum time away from the nest. Although there is regional variation, most nests are built within 0.8 km of a sea coast, lake, or river, and many are considerably closer (Snow 1973). Throughout most of its range, the bald eagle is expected to use [illegible] same nest year after year. It is a progressive structure; [illegible] year the breeding pair refits the old nest, virtually building [illegible] new one on top of the old. Both the male and female share this labor, which can be completed within a few hours or [illegible] take as long as a few days. Because the nests are progressive structures, they can acquire great dimensions over the years."

Bald eagles attain their adult weight by the first year although sexual maturity is not reached until the fifth or sixth year. Under protected conditions, bald eagles in captivity have exhibited life spans exceeding 50 years (Snow 1973).

5.12.5 Food Habits

Summarizing the literature on bald eagle feeding, the U.S. Army Corps of Engineers (1979) stated:

> "Throughout its range, the northern bald eagle exhibits an amazing adaptability in food habits. The birds are generalized predators, capable of utilizing a wide variety of prey items including fish, other birds, mammals, and invertebrates - any of which may be consumed both as live prey and carrion. Few other raptors are as capable of exploiting so many food resources. Proportions of prey types utilized varies with the time of year, geographic location, particular habitat, and even the age of an eagle. Previous experience or preference, which can be variable with individual eagles, also influence what is eaten (Hancock 1964)."

When available, fish is the preferred food of bald eagles (Snow 1973). The U.S. Army Corps of Engineers (1979) cited several observations and an experiment by Welty (1953) demonstrating this preference. In western Washington, salmon is the most frequently consumed species, although other fish are consumed depending on season and location. Resident salmon are eaten in spring and summer, whereas spawned-out salmon and their carcasses provide an important wintering food.

The U.S. Corps of Engineers (1979) stated:

> "Studies of the food habits of bald eagles inhabiting various shoreline habitats reveal the importance of fish in the diet. On San Juan Island in Washington, Retfalvi (1970) determined through pellet analysis that fish comprised 50.8 percent of the year-round diet of bald eagles. Birds composed 27.9 percent and mammals 21.3 percent of the fare of these eagles. Along the coast of southeastern Alaska, 65.7 percent of the diet of bald eagles consists of fish, and 18.8 percent of birds (Kalmbach et al. 1964)."

The U.S. Army Corps of Engineers (1979) considered the use of carrion and concluded:

> "Whether bald eagles prefer to capture live fish or utilize carrion is debatable. During the spawning runs of salmon, which occur during fall and winter, it seems that the highly opportunistic birds would primarily utilize the more easily accessible dead or dying fish. Indeed, Servheen (1975) observed bald eagles wintering on the Skagit River to eat salmon only after they had spawned and died. He observed eagles capture live fish only twice, both times when salmon carcasses were unavailable. Kalmbach et al. (1964) believe that bald eagles in southeast Alaska primarily consume fish as carrion, with less than 10 percent of salmon captured alive."

The Klamath Basin eagle population feeds primarily on sick or injured waterfowl, fish, miscellaneous carrion, and rodents. Evidence at Hanford, in eastern Washington, suggested that waterfowl were the chief late winter food (Fitzner et al. 1980). At both Klamath Falls and Hanford, hunter-killed and crippled birds are most frequently taken. Of the waterfowl taken by eagles in the vicinity of Lake Pateros and Rufus Woods Lake, in eastern Washington, 75 percent were American coots, while widgeons and mallards each comprised roughly 5 percent of the diet (Fielder and Starkey 1980). These data may reflect relative abundance of species, rather than eagle preference.

Eagles are variable and opportunistic in their feeding habits. Along the mouth of the Columbia, they may scavenge along rocky shorelines, sandy beaches and tide flats, feeding on molluscs, crustaceans, dead fish, and other carrion. Within the estuary and up river, they may feed on spawned-out anadromous fish, resident fish, small mammals, and carrion.

5.12.6 Factors Affecting Distribution and Abundance

5.12.6.1 Natural factors. A habitat's carrying capacity for breeding birds is limited by the interaction of birds known for their large territorial requirements. Welty (1962) reports bald eagle territories of approximately 2,500 hectares (1 mi^2). Territory requirements, however, vary considerably, often depending on the characteristics of the environment.

Availability of food and the presence of suitable nest trees are two specific environmental components of the breeding territory. Reduced salmon runs in recent years may account for decreases in carrying capacity, although the significance remains undetermined. Hunt et al. (1980) demonstrated that wintering eagles foraging on northwest rivers in Washington and southern British Columbia during years when a synchrony of low salmon runs and certain weather factors occur may be limited by food availability. Successful breeding may also be limited by the scarcity of nest sites near open water (large trees with sturdy branches at sufficient heights) and tree stands exhibiting large crowns with abundant cover (Grubb 1980).

Several natural factors may have an impact on eagle populations. Severe weather may affect the productivity of eagles, damage nests with eggs or young, and/or destroy potential nesting, perching, or roosting trees. Large, old trees are especially susceptible to windfall and lightning strikes. Siltation of streams from the recent eruption of Mt. St. Helens have temporarily reduced the availability of fish and other food sources in the lower Columbia River.

Sherrod et al. (1977) and Hunt et al. (1980) also found that the primary limiting factor for wintering eagle populations may be food availability, although adequate perching and roosting sites were important. Virtually all eagles perch within 50 m (164 ft) of water during daylight hours (Stalmaster et al. 1979). Similarly, roosting sites within several kilometers from water are preferred.

In many wintering areas, a significant portion of the diet of bald eagles comprises dead, sick, or hunter-crippled waterfowl. Eagles likely contract avian cholera through scavenging on carcasses of waterfowl which have died of the disease (U.S. Army Corps of Engineers 1979).

Fratricide, which typically limits survival to only one fledgling, often contributes to nestling mortality. More than one young per nest, however, fledge consistently in some populations in Alaska, suggesting that higher productivity is possible under optimum conditions (Bent 1937; Brown and Amadon 1968).

Nest predators are most frequently avian robbers, including gulls, ravens, and crows (Chrest 1964; Hensel and Troyer 1964), and less frequently ground predators, such as raccoons (Nash et al. 1980) and even black bear (McKelvey and Smith 1979). The extent to which these animals seriously influence normal eagle populations under natural conditions is undetermined, but nest predation probably accounts for only occasional deaths.

5.12.6.2 Human factors. Juvenile and adult eagles have few enemies other than man. Throughout their range, man has directly and indirectly reduced their populations by shooting, poisoning, chemical pollution, and habitat destruction. In a study by Coon et al. (1970) of autopsied eagles from throughout the United States and Canada, 82 percent of mortality was attributable to shooting, 13 percent to impact injuries, four percent to trapping, and two percent to electrocution.

Shooting has been the most common cause of bald eagle mortality throughout this century. Possibly up to 500 bald eagles are illegally shot each year (Braun 1975). Coon et al. (1970) performed autopsies on 64 bald eagles from 21 of the coterminous states plus 9 birds from Alaska and 3 from Canadian provinces. Trauma was found to be the most frequent cause of death, of which 62 percent were attributed to gunshot injury. Studies at the Patuxent Wildlife Research Center for the periods 1966 to 1968, 1969 to 1970, and 1971 to 1972 found mortality was due to shooting 40 percent, 46 percent, and 35 percent of the time, respectively (Mulhern et al. 1970; Cromartie et al. 1975). Autopsies performed on 276 bald eagles during the period 1964 to 1974 found illegal shooting to be the most common cause of death.

The shooting of bald eagles by humans on San Juan Island, Washington, has resulted in the loss of at least 75 percent of the annual production (Retfalvi 1965).

Bald eagles have been seriously affected by biologically amplified pollutants, principally persistent chlorinated hydrocarbon pesticides and their metabolic derivatives (Hickey and Anderson 1968; U.S. Army Corps of Engineers 1979). Reproductive failure caused by the concentration of these substances may be the cumulative product of consumption of contaminated prey.

Organochlorines cause egg shell to thin and break, resulting in the failure of embryos to hatch (Snow 1973; U.S. Army Corps of Engineers 1979). Within the Columbia River Estuary, increasing levels of PCB's observed in mink (Henny, C. pers. comm.) have paralleled decreasing reproductive success in eagles and are therefore implicated as a possible cause of declining eagle populations.

In a study of the comparative productivity of six bald eagle populations, Sprunt et al. (1973) found widely varying rates of reproductive success. They concluded the principal factor in such large differences to be the relative contamination of various populations with hydrocarbon pesticides.

Another threat comes from the use of poisons for predator and rodent control. Although only minimal doses are supposed to be used in poison baits, sometimes the dose exceeds minimal levels and a poison such as 1080, which is specifically designed to kill canines, may kill eagles. Thallium sulfate is dangerous to eagles, and at least eleven bald eagles were poisoned by it in Wyoming (Sprunt 1972).

Many areas which once provided optimum habitat for eagles have been greatly modified and, in some cases, virtually destroyed by humans. Bald eagles prefer to nest and winter near water, but humans prefer shorelines, too. In the United States, extensive river, lake, and coastal habitats have been altered by construction of housing developments and industrial complexes, which require large amounts of water.

Timber harvesting has modified vast expanses of land, reducing the quality of these areas as eagle habitat. Harvesting of timber along shorelines is especially critical. Unless a substantial shoreline fringe is left, the breeding eagle population is forced from the area for lack of suitable habitat (Corr 1974).

Researchers generally agree that human activities in the vicinity of bald eagle nesting sites negatively affect populations (Snow 1973). Juenemann (1973) found that although there was little correlation between human disturbance and nesting success on an individual territory basis, when the population as a whole was considered, increased disturbance resulted in reduced activity and productivity.

Human activities may have increased the average size of territories in the San Juan Islands and Olympic Peninsula of Washington (Grubb 1976). A comparatively smaller resident breeding eagle population, having fewer available nest sites due to logged beach frontage, with a concomitant increasing human population, are postulated to have fled to larger territories.

Studies of wintering bald eagles also indicate a variable tolerance to human activities by different populations (Servheen 1975; Stalmaster 1978; Hunt et al. 1980; Russell 1980). Evidence suggests that in wintering areas where the habitat is optimal, bald eagles will tolerate a high level of human activity. At less preferred sites, however, human activities are more disruptive and can cause a shift in habitat use patterns (Steenhof 1976) or even dispersal from the area (Shea 1973).

Stalmaster (1976) conducted studies on the effects of various human activities on bald eagles wintering on the Nooksack River in western Washington. The activity most disruptive to eagles was boating along the river. Close-range viewing of the birds, fishing within their sight, and hunting (because of the adverse reaction of eagles to gunshots) were also disruptive. The study found that normally disturbing activities such as general foot traffic adjacent to the river were better tolerated by eagles if these activities were partially concealed from view by vegetation buffers. Stalmaster determined that eagles become habituated to routine human activities on the riverbank, but disturbances on river bars or the river itself continued to be highly disruptive.

Electrocution is another human-related cause of mortality. This is primarily a problem with older transmission lines (Sprunt 1972). Since power poles often provide the only available perches in treeless country, they are frequently used by birds of prey. The way an eagle lands and takes off influences whether or not it will be electrocuted. Electrocution is a minor factor compared to shooting, but losses in some areas may be considerable. Data are insufficient to determine the impact of electrocution on bald eagle populations (Sprunt 1972).

5.13 COLUMBIAN WHITE-TAILED DEER

5.13.1 Introduction and Description

The Columbian white-tailed deer (*Odocoileus virginianus leucurus*) is a medium-sized deer with a characteristic long, white tail that is conspicuously raised in flight. Its body length is about 2 m (6 ft) and, unlike the sympatric black-tailed deer, it has no brow tine. Other distinguishing features of this deer include a white pelage extending the full length of the ventral surface and undersides of the legs, white eye rings, and a tail that is dorsally brown and ventrally white (Davison 1979a,b). It is one of about 30 races of white-tailed deer, but unlike most of the other races, it has an extremely limited range.

5.13.2 Resource Value and Estuary Usage

The original range of the Columbian white-tailed deer is unknown, but may have extended from Roseburg, Oregon north to the southern end of Puget Sound in Washington (Martinsen et al. 1980). Deer were extirpated throughout most of their original range by 1900. In 1940, Scheffer estimated that there were 500 to 700 deer along the lower Columbia River. As of 1978, the species is classified as endangered in Washington and Oregon by the U.S. Department of Interior.

Today, there are three west coast Columbian white-tailed deer populations: two along the lower Columbia River in Clatsop and Columbia counties, Oregon, and in Wahkiakum Bounty, Washington and a third in the state refuge between Roseburg and the north Umpqua River, Oregon.

5.13.3 Population and Status

Population estimates for the Columbian white-tailed deer are incomplete. The mainland portion of the Columbian White-tailed Deer National Wildlife Refuge contains the greatest numbers (Table 5-19). Here populations are estimated at 250 to 300 deer, including 30 to 40 individuals on

Table 5-19. Estimated numbers of the mainland Washington white-tailed deer on the Columbian White-tailed Deer National Wildlife Refuge in 1939, 1972-73, and 1974-77.

Year	Estimate[a]	Method	Source
1939	250-350	Interviews	Scheffer (1940)
1939	200	Interviews	Lauckhart (1940)
1972-73	200-230	Spotlight-evening counts	Suring (1974)
1974 (Nov)	214 (127-370)	Schnabel mark-recapture estimates	Gavin (1979)
1975 (Nov)	180 (124-265)	Schnabel mark-recapture estimates	Gavin (1979)
1976 (Nov)	164 (92-306)	Schnabel mark-recapture estimates	Gavin (1979)
1977 (Nov)	202 (126-333)	Schnabel mark-recapture estimates	Gavin (1979)

Source: Martinsen et al. (1980).

[a] Confidence intervals (95%) are in parentheses.

Tenasillahe Island (Martinsen et al. 1980). Deer estimates off the refuge range from 100 to 200 individuals (Martinsen et al. 1980). Martinsen et al. (1980) reported that deer occur in the following areas off the refuge:

> About 30 on Puget, Brown and White Islands in Wahkiakum County, Washington.
>
> From 70 to 80 on Wallace Island in Clatsop and Columbia counties, Oregon (Davison 1979a,b). Additional deer were observed on Little Wallace, Anundes, Kinnunen Cut, and Skull Islands in Columbia County, as well at the Columbia River bottom area between Westport and Woodson in Clatsop County. A few were observed in Clatskanie Columbia County.
>
> Approximately 8 to 12 deer on Karlson Island, Lewis and Clark NWR, Clatsop County, Oregon.
>
> About 1,900 in the vicinity of Roseburg in Douglas County, Oregon. This is the largest single population in the west coast.

There have been reports of occasional sightings of Columbian white-tailed deer in other areas along the lower Columbia River, but the locations listed above are believed to contain the only populations of any importance (Davison 1979a,b).

Deer densities on the refuge are estimated at one deer per 4 to 5 ha (9 to 12 acres). Off-refuge island populations are approximately one deer per 4 ha (10 acres) (Davison 1979a,b). Populations on the refuge were stable from 1939 to 1977, fluctuating between 164 and 350 deer. In general, high fawn mortality and low to moderate adult mortality maintain stable population size.

Management practices on the mainland Washington refuge have resulted in a deer population stabilized between 200 and 250 deer on 900 ha (2,250 acres) from 1972 through 1979, suggesting that the carrying capacity under the existing mixed natural and agricultural plant community is at an average density of one deer per 4 ha (10 acres). Populations in comparable habitats but at lower densities, such as the 50 deer estimated in 810 ha (2,000 acre) Tenasillahe Island, may be taken as being below capacity and capable of expansion.

5.13.4 Life History

Deer attain full adult size in four to five years. Average adult males weigh 68 kg (151 lbs) and adult females 50 kg (111 lbs).

Sexual maturity in Columbian white-tailed deer is reached in one to two years, with does breeding at 1.5 years (Gavin 1977). Mean age of death for 7 females and 3 males was estimated at 5 and 3 years, respectively, and resightings of marked deer indicated they reached 6-7 years of age (Suring 1974).

Rutting begins in the first week in November, reaches its peak during the second week, and ends by the beginning of December. Peak fawning occurs in early to mid-June. Very old and young does typically have a lower fawn-per-doe ratio. Recruitment was higher for females at least 3.5 years old which produced 0.75 to 0.85 fawns, and lower for 2.5 years old which only produced 0.38 fawns (Gavin 1979). No significant contribution was made by 1.5 year old does. Suring (1974) reported that few twins are born and that many does are without fawns each year. However, more recently Brittell et al. (1976) and Gavin (1979) reported higher fawn-to-doe ratios.

The habitats most heavily used by Columbian white-tailed deer are the open canopy forest and park forest (Suring and Vohs 1979). Both of these forest habitats are characterized by a noncontinuous tree canopy. Closed canopy forests are occasionally used for cover. The park forest habitat is preferred in fall, winter, and spring by providing both cover and forage, and in winter, by providing some protection from the cold. Open canopy forests are more heavily used in spring and summer when the weather is moderate. Clearings dominated by thistle (*Cirsium spp.*), reed canary grass (*Phalaris arundinacea*), velvet grass (*Holcus lanatus*), alta fescue (*Festuca elatior arundinacea*), and common rush (*Juncus effusus*) are used primarily for feeding, although tall low-lying stands of rush provided cover. The greater use of thistle sites compared to improved pastures was attributed to the lack of cover in managed pastures. Improved pastures and reed canary grass pastures receive relatively low use even though this vegetation type is abundant. Suring and Vohs (1979) discovered that deer preferred areas of the Columbian White-tailed Deer Refuge with interspersed cover types, from which cattle have been excluded. The importance of cover is substantiated by the few deer observed feeding in the daytime more than 250 m (820 ft) from woodlands.

The species is largely sedentary, although daily movements between cover and forage areas occur. Suring (1974) reported that the average home range for does was 39 ha (95 acres) and for bucks, 93 ha (228 acres). Deer are good swimmers and frequently move from island to island (Eaton 1975).

Deer on Wallace Island inhabit dense marshy woodlands more closely resembling the historical habitat for the species (Davison 1979a,b). Habitat use may be divided between nearby islands. For example, the same herd of deer (Puget Island Herd) are believed to use Brown Island primarily as cover and the pastures and cornfields on Puget Island to forage (Martinsen et al. 1980).

5.13.5 Food Habits

The diet of Columbian white-tailed deer is a function of forage quality, availability, and the presence of physical and chemical defenses in plants. Contrary to the findings of Suring (1974) and Suring and Vohs (1979), Dublin (1980), after analysing gut and fecal samples, found that Columbian white-tailed deer did not prefer herbaceous plants throughout the year. Seasonal preference indices showed a shifting diet: blackberries

(Rubus spp), Pacific ninebark (Physocarpus capitatus), salal (Gaultheria shallon), dogwood (Cornus stolonifera), and other browse important in fall, winter and late summer; fruits and berries in late summer; orchard grass, timothy and other grasses in early spring; and yarrow, woodland phacelia and other forbs in spring, summer and early fall. Dublin concluded that the Columbian white-tailed deer shift their diets to capitalize on the highest protein and nutrient content of vegetation at any given time.

5.13.6 Factors Affecting Distribution and Abundance

5.13.6.1 Natural factors. The limited range and small population size make the race susceptible to natural catastrophies, particularly flooding, although flood control measures taken in the Columbia River basin have reduced that probability.

Natural causes of mortality of Columbian white-tailed deer include nutrition stress, parasitic and bacterial infections, predation, and drowning. More fawns are killed by these factors than adults. High fawn death rate (over 50 percent mortality the first summer), indicate that nutritional and physiological stresses are a major cause of mortality (Gavin 1979). Additionally, internal parasites such as stomachworms (Haemonehus sp.) or bacterial infections, including necrobacillosis (Fusobacterium necrophorum) are frequently found in dead deer and may be the cause of death or major contributors to death (Columbian White-tailed Deer Recovery Team 1977).

Large natural predators have been removed from the lower Columbia River area, although cougars (Felis concolor) may take an occasional deer. Coyotes, however, account for 50 to 80 percent of the fawn mortality observed in the Columbian White-tailed Deer National Wildlife Refuge (Martinsen et al. 1980), but probably are not a factor in adult mortality.

5.13.6.2 Human factors. Clearing of forested areas within the lower Columbia area in the late 1800's and early 1900's probably improved habitat conditions and caused an increase in deer abundance in Washington and Oregon. Later, as more and more parcels of land were cleared, habitat suitability was reduced below optimum conditions and deer numbers declined. Such a sequence is typical for edge species in developing areas (Taber 1973).

Early settlers cleared woody vegetation adjacent to rivers for intensive farming. Fire suppression reduced the extent of open, savanna-like habitats in some valleys (e.g. Willamette Valley), especially along rivers (Martinsen et al. 1980). Since the deer were probably concentrated in the narrow riparian strips along major rivers and streams, their habitat was vulnerable to alteration by early settlers who also chose these sites.

As a result of the Columbian white-tailed deer's precarious status, the Columbian White-tailed Deer National Wildlife Refuge was established in 1972. The refuge is about 2,105 ha (5,200 acres) in size and includes Tenasillahe Island, Hunting Island, and Price Island, and a portion of the Columbia River edge in Washington near Cathlamet. The refuge is managed to protect and improve conditions for the deer. A Recovery Team has developed a deer recovery plan which encompasses life history studies, reintroduction into former range, and captive herd studies, with the goal of removing the deer from the endangered list (Martinsen et al. 1980).

Early haying accounts for an unknown number of fawn deaths. Newborns are killed when fields are mowed in early and mid-June before fawns can escape from cutting machinery. Although early July harvests significantly reduce fawn loss, they preclude a second harvest essential to providing winter forage for deer (Columbian White-tailed Deer Recovery Team 1977).

Some deer which disperse from the refuge area are shot during deer hunting season, but such losses do not seriously affect the status of the lower Columbia population (Brittell et al. 1976). In fact, hunting on the Umpqua herd in Douglas County has been suggested as the cause of greater birth rates and a healthier herd (Brittell et al. 1976).

Competition with livestock for cover and food is another important limiting factor and Columbian white-tailed deer habitat, preferably, should not be grazed (Brittell et al. 1976; Suring and Vohs 1979). Poaching is also considered a significant limiting factor (Martinsen et al. 1980). Dog harassment results in approximately one deer death on the refuge per year, but off the refuge dog harassment is probably much higher.

The siting and construction of energy facilities such as power plants, transmission lines, and utility substations could eliminate or modify deer habitat by removing food and cover. The extent of impact would depend upon the degree of habitat removal or alteration, and the resulting cover and edge condition changes.

CHAPTER 6.0 SITE-SPECIFIC CONFLICTS

6.1 SUMMARY

Although this study focuses on the Columbia River Estuary, it is recognized that most energy facilities will be sited upstream. For this purpose the analysis of future energy-related uses encompassed a study area extending upriver to Portland (river mile 102).

The upstream boundary of the estuary is that part of the river subjected to tidal, saline waters that reach one or two miles above Harrington Point (river mile 23) (Neal 1972). The Columbia River Estuary Data Development Program defined the estuary for the purposes of its research program as the area extending from the mouth to river mile 46 at the eastern tip of Puget Island (Envirosphere 1980). The CPCR also used the eastern tip of Puget Island as the inland boundary of the coastal watershed unit which included the Columbia River Estuary. For purposes of this study, the upstream extent of the estuary shall be defined by the salinity intrusion at river mile 25 (Neal 1972). Upstream of river mile 25 is considered the lower Columbia River.

Table 6-1 summarizes the existing and possible energy developments for the lower Columbia River and Estuary. Notice that proposed developments are fewer in number and kind for the estuary study area and generally lower in probability as well. Because the surface area of the river is far less per river mile than the surface area of the estuary, development pressures along the river are more concentrated in area as well as distance.

Within the estuary study area, there were eight possible sites identified for OCS support, three sites for potential coal transshipment terminals, an existing 8,000 kW back-up fossil-fuel power plant (by Youngs Bay) which is no longer in use, and a small hydro power (17 MW) site which may be developed on a tributary (Grays River) to the estuary. Developments bordering the estuary are more likely in Oregon. Development of one or two OCS support sites would decrease the probability of development at the remaining sites, just as development at one site for a coal transshipment terminal will decrease the probability of development at other proposed sites. Hence, within the estuary, energy related developments over the next 25 years will probably be one coal terminal and a couple of OCS support bases. One of these OCS support bases may include fabrication yards for constructing drilling rigs and platforms. This will depend on exploration for oil or gas and subsequent base sales of OCS tracts in the region. Development of a small hydro facility on the Grays River would impact fisheries dependent on that tributary, but would have minimal impact on the estuary.

Table 6-1. Current (1981) and potential energy related facilities or activities in the lower Columbia River and Estuary.

River Mile	State	OCS Support	Gas Exploration	Hydro Power	Nuclear Power	Fossil Power	Refinery	Petrochemical	Synfuels	Pipeline Xing	Transmission Line X	Coal Gasification	LNG/LPG	Fuel Storage	Other	Comments
3	W	O														
3-1/2	W	O														
4	W	O														
5	W	O														
10	O	L														
11	O	L	L													Fabrication yard for OCS rigs
11	O	L														
13	O	L	?													
14	O					E										No longer in use
18	O	H														
23	W			M												Grays River
27	O			L												Big Creek
27-1/2	O				O											
37	W		L													Tenasillahe Island
37-1/2	W				O											
40	W		H								E/H					Upgrade power line crossing
42	O		L													Puget Island
47	O		H													Oregon side, miles 42-49
50	O														E/M	Gas pipeline near estuary, may enlarge
54	O	L				E/M	L					M	L			Beaver combined cycle plant at site
58	W														?	Port of Longview wants to develop
63	-										E					
65	O						M	M							M	Port of St. Helens. May have two projects
65	W														E	
66	W														H	Calcine coke shipment facility planned
70	W		L				L	L	L				L		M	Cottonwood Island, room for 3 projects
72	O				E/L											
72-1/2	W		H													EIS (Draft) Filed
73	W			M												Kalama River
73	W														M	Industrial filled site
74	W							E/M								
76-1/2	W							E								
77	-									E						Gas pipeline
80	W							?	?					?		Martin Island
81	W								?						?	Burke Island
81	O						?	?								Deer Island, south end
82	O							E/H								
82	O						?	?						?		
87	W			E/?												Lewis River
87	-									E						
100-1/2	-									E						
102	O	M														

E = Existing
M = Medium Probability
O = Highly Unlikely
H = High Probability
L = Low Probability
? = Unknown

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From the estuary to the eastern end of Puget Island, the most likely energy developments will be for natural gas exploration and subsequent development, if leased areas have sufficient reserves to market. Sites of possible gas reserves exist between river miles 35 and 49 in Oregon and Washington. Some areas have already had lease sales in both states. Other energy developments within this portion of the lower Columbia River include upgrading a BPA transmission line river crossing, and siting a possible small hydro power facility on the tributary Big Creek. Also, there are two sites which were evaluated by WPPSS for nuclear power plants. In view of present financial difficulties, the probability of WPPSS ever building facilities there is virtually zero. Impacts to fisheries dependent on Big Creek are the only potentially significant, long-term problem from energy developments in this part of the lower river.

Most of the existing and anticipated energy developments within the study area are in the lower Columbia River, between Portland and Puget Island. Many of these facilities are dependent on marine shipping to either deliver raw materials or fuel [illegible] to export fuels or products. The shipment of these materials by ma[illegible]s increases the risk of spills of crude petroleum, fuel oils, or [illegible] chemicals in the estuary or lower Columbia River where currents may c[illegible]y the spill throughout the estuary. Additional shipments associated with new developments will increase this risk. New or expanded energy facilities foster the demand for deepening the Columbia River channel and the entrance of the estuary. Additional dredging may result that will affect the estuary and lower river.

Numerous different proposals indicate that some development is very likely at several selected sites. At river mile 54, in Oregon, there is an existing combined cycle generating facility that now burns mostly natural gas. This facility may expand and be considered for conversion to a coal gasification plant to provide fuel. The same site is also considered for a coal terminal, a refinery, and an LPG terminal. The Port of St. Helens owns land around river mile 65 which may support two proposed projects, a refinery and a petrochemical facility. At river mile 70, Cottonwood Island has been extensively filled with debris dredged from the Mt. St. Helens eruption, and there is acreage sufficient for three developments. Proposed energy developments include a coal terminal, a refinery, and petrochemical, synfuel, and LNG facilities. Nonenergy related developments may also occur there. From river miles 80 to 82, numerous energy proposals exist, many being slated for siting on Martin, Burke, and Deer Islands.

Between Puget Island and Portland, there have been suggested sitings for four coal terminals, two dams on tributaries, one additional nuclear power plant, expansion of a gas fired power plant, five refineries, five petrochemical plants (and expansion of two of three existing ones), three synfuel facilities, one coal gasification facility, one LNG and three LPG facilities, and one biomass conversion facility. Within the same area, there already exists one hydro power dam on a tributary, one nuclear power plant, one fossil-fuel power plant, three petrochemical plants, three pipeline crossings, one gas pipeline near the river, one transmission line crossing, and a fuel storage area. Nonenergy industries also occur along the river, especially near Longview, Washington where secondary impacts from increased population are most likely to be manifested from any new developments.

6.2 SITE-SPECIFIC ASSESSMENTS

Site-specific assessments of the energy related facilities and developments in the study area are presented in Table 6-2. The table is arranged by river mile, indicating the side of the river the development is, or will be, sited (by state). A description of the development, a qualitative probability, a description of the project impact characteristics within estuarine, riverine, and upland/riparian habitats, areas of concern, species of concern, and other comments are also indicated. Areas and species of concern were determined from various compilations (Kujala 1976; Sutherland 1979; Tabor 1976; Dames and Moore 1981) and referenced accordingly. Details on specific facilities are presented in Chapter 2. Project impact characteristics are derived from Chapters 2 and 3, and are more specific when actual proposals and environmental studies have been conducted (such as for the Kalama Coal Terminal, the Trojan Nuclear Power Plant, and OCS support facility for the Skipanon River).

6.3 CUMULATIVE IMPACTS

Cumulative impacts are generally defined as long-term effects that accumulate over space and time. They may be onsite, which are essentially small impacts over a long time, or offsite, which result from down stream movement of effluents.

This section emphasizes energy developments, but it must be remembered that these occur in concurrence with agriculture, suburban development, recreational activities, etc.

There are important regional, microclimatic, edaphic, and geographical variations within the Columbia River Estuary which will determine the magnitude and importance of cumulative impacts to soil, vegetation, animal communities, water, and air. Recognizing these differences in the estuary, some changes, nevertheless, will take place as a result of estuarine development. To effectively predict cumulative impacts, a thorough knowledge of the Columbia River estuarine mechanics and biological driving forces are necessary.

Cumulative effects is a complex and conceptually difficult subject to capsulize. Nevertheless, several cumulative impacts may be expected and are summarized in the following text.

The most significant cumulative impacts to the estuary currently arise from the main stem hydroelectric dams which have produced an increase in temperature, a decrease in flooding, an increase in estuarine sedimentation, and a partial blockage of fish passage. Additionally, the maintenance

Table 6-2. Current (1981) and potential energy support facilities in the lower Columbia River and Estuary, and environmental concerns.

River mile	State	Facility/site	Probability Yrs.	Probability level	Projected sources of environmental impacts	Environmental concerns Areas	Environmental concerns Species	Comments
3 to 5	WA	4 possible staging and storage sites between Ilwaco and Chinook in Baker Bay: support for OCS oil and gas development	0-5 5-15 15-25	Very low Very low Very low	ESTUARINE Considerable dredging of subtidal and intertidal mud and sand flats required for access to sites Dock construction Dredged material disposal	Concentrations of benthic organisms in Baker Bay and marsh habitat near shore	Marsh hawk Chinook & coho salmon fingerling nursery east of Sand Island Western glaucus gulls nesting on East Sand Island Dungeness crab nursery and feeding in Bakers Bay Waterfowl nesting and feeding Oreas angel wing butterfly Nearby breeding of pelgren cormorant Small concentration of bald eagles Caspian tern roosting & feeding area	
					RIVERINE	Chinook River hatchery		
					UPLAND/RIPARIAN Sites are 60 to 200 acres Dredged material disposal is an environmental problem Major road improvement Railroad probably needed Secondary developments related to an increase in employment		Oreas angel wing butterfly, Pacific giant salamander, and Dunn's salamander Nearby breeding and roosting area of bald eagles	
10	OR	OCS oil and gas development support (Tansy Point) Staging area	0-5 1-15 15-25	Low Low Low	ESTUARINE Dredge and fill Dock construction	Concentrations of benthic organisms close to shore and marsh habitat to the south Oregon State Univ. has a research site in the marsh to the south of Tansy Point Seal haul-out area at Desdemona Sands 1-1/2 n.m. NNE of site National Marine Fisheries Service Research site at Hammond, 1 a.m. NW of site Juvenile Chinook salmon feeding area east of Tansy Point	Birds: western grebe, double-crested cormorant, Cooper's hawk, marsh hawk, bald eagle, short-billed dowitcher Fish: starry flounder, Chinook salmon.	Site is close to the shipping channel.
					UPLAND/RIPARIAN Secondary developments related to increase in employment			

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Table 6-2. Continued.

River mile	State	Facility/site	Probability		Projected sources of environmental impacts	Environmental concerns		Comments
			Yrs.	level		Areas	Species	
11	OR	OCS oil and gas development support (Skiparch Waterway) Mobile dwelling fabrication staging areas	0-5 5-15 15-25	Low Low Low	ESTUARINE Dredge and fill Dock construction UPLAND/RIPARIAN Staging areas - 2 sites of 30 / 50 acres Fabrication yard site is 330 acres Secondary development with increase in employment (a large fabrication yard may employ 1,000 people)	Marsh areas to west and to southeast in Youngs Bay Waterfowl feeding by marsh to southeast Benthic organisms between site and shipping channel Seal haul out area at Desdemona Sands Oregon State Univ. research site at marsh to west of site Juvenile Chinook salmon feeding area at mouth of Skipanon River and to east and west	Crayfish migration in waterway Birds: western grebe, double crested cormorant, Cooper's hawk, marsh hawk, bald eagle, short-billed dowithcer Fish: starry flounder, Chinook salmon	Influx of large work force is one of the main impacts of OCS oil and gas development support Lower Skipanon River has naturally poor flushing characteristics
11	OR	Coal terminal (Skipanon waterway)	0-5 5-15 15-25	None Low Low	ESTUARINE Dredge and fill Pier construction out to channel Dredge to about 48' deep Coal dust 2 to 3 vessels a week Dredge river bar to 55'-60' UPLAND/RIPARIAN Coal dust/coal storage 4 to 5 unit trains per day Noise	Same as for OCS oil and gas development support facility proposed at this site	(same)	Flushing considerations more important here due to greater dredging depths & coal dust and /or leachate from storage and/or oil spills from vessels
13	OR	OCS oil and gas development support (Pier 3, at Smith Point)	0-5 5-15 15-25	Low Low Low	Area already impacted by port development ESTUARINE Perhaps some additional filling with dredged materials	Young's Bay benthic organisms juvenile Chinook feeding area	Chinook salmon *Corophium* spp	Some type of port development is likely but not necessarily energy related
13	OR	Coal terminal	0-5 5-15 15-25	? ? ?	As above, but ESTUARINE Additional pier construction and dredging (See coal terminal, RM 11) UPLAND/RIPARIAN Coal storage, coal dust Unit trains	See RM 13-OR, OCS support	See RM 13-OR, OCS support	See RM 13-OR, OCS support

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Table 6-2. Continued.

River mile	State	Facility/site	Probability Yrs.	Probability level	Projected sources of environmental impacts	Environmental concerns Areas	Environmental concerns Species	Comments
14	OR	Pacific Power & Light Co. 8000 kW back-up power plant by Youngs Bay	Existing facility		Emissions and discharges related to occasional operation Eventual removal (similar to construction activity impacts)	Bald eagle feeding area, marsh habitat & benthic organisms to the south Young's Bay	Bald eagle	Not in use. May be removed soon
18	OR	Coal transhipment (Tongue Point) 5-10 million tons throughput per year	0-5 5-15 15-25	Low High Medium	ESTUARINE SUBTIDAL Bar dredged to 55'-60' Channel dredged to 48' Turning basin dredged Shipping increases (100+ vessels a year, or 2-3 vessels/week)	Adjacent to Lewis and Clark wildlife refuge boundary SW of Tongue Point and around Taylor Sands N and E of Tongue Point Haulout area at Taylor Sands	Chinook and Coho salmon fingerling nursery on north and west side of Tongue Point Concentration of benthic organisms Sturgeon fishing hole Harbor seal	Effluents from coal storage area could be toxic if runoff occurs. Site already partially developed, abandoned port, log storage Harbor used for log storage. Fugitive dusts may cause problems. State supports this development (Oregon HB2664 June 1981).
					ESTUARINE INTERTIDAL Expansion & upgrading of mooring dolphins and/or piers Dredging turning basin to 40' and also at ship mooring site Propwash effects from ship and tugs	SE of Mott Basin Green Island Adjacent to wildlife refuge area SW of Tongue Point and around Taylor Sands	Waterfowl resting area Bald eagle feeding and swan wintering area Waterfowl Concentration of polychaetes and amphipods.	
					UPLAND/RIPARIAN 200-350 acres Railroad loops and some filling docking area Fill required at coal storage site Unenclosed coal storage area for about 1 million tons 4-5 unit trains per day	Natural area identified by Nature Conservatory (wildlife area) at base of Tongue Point Adjacent to wildlife refuge boundary		
					SUPPORT REQUIREMENTS Upgrading of BN Railroad line from Portland to site			
23	WA	Small hydroelectric dam on Grays River, 7 miles NE of its confluence with the Columbia River 17; MW 50' high concrete diversion dam	0-5 5-15 15-25	Low Medium Low	ESTUARINE Negligible	None	None	No impoundments on river at present time Fish passage facility planned for dam

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Table 6-2. Continued.

River mile	State	Facility/site	Probability		Projected sources of environmental impacts	Environmental concerns		Comments
			Yrs.	level		Areas	Species	
23 continued					RIVERINE Inundation of app. 100-200 acres of bottomland Significant reduction or elimination of flow Barrier to fish	Gray's River hatchery Spawning beds	Salmon	Access used to site already
					UPLAND/RIPARIAN Inundation of existing riparian habitat Concrete-lined tunnel 11,200 ft. long into powerhouse 1900 acre ft. capacity, 50 ft. high Powerhouse construction Upgrading existing road to site 7 miles of transmission line		Olympic salamander, Dunn's salamander, Pacific giant salamander	
27	OR	Small hydro electric dam (Big Creek) 8 miles from mouth of creek 1.1 MW capacity 60' head 1,500 acre-feet impoundment	0-5 5-15 15-25	None Low Low	ESTUARINE Negligible	None	Great blue heron	
					RIVERINE Inundation Change in patterns of stream flow Barrier to migratory anadromous fish	Karlson Island great blue heron colony >300 nests Salmon spawning habitat Big Creek hatchery	Anadromous salmonids	
					UPLAND/RIPARIAN 5 miles of transmission lines.			
27-1/2 and 37-1/2	OR WA	WPPSS Nuclear Power Plant Study Areas	0-5 6-15 16-25	None None Very Low	(Trojan style plant bordering river)	RM 27-1/2 Grays Bay-Food production for Waterfowl RM 18-35 Lewis & Clark National Wildlife Recreation Area RM 28 Fish hatchery at Gnat Creek and at Big Creek	Wintering waterfowl Great blue heron nesting Bald eagle feeding Juvenile Chinook feeding	CREST designated as rural, natural & conservation WPPSS having severe financial problems
						RM 37-1/2 Marshes on islands and Columbian White-tailed Deer National Wildlife Refuge RM 37 Elochoman River Hatchery	Columbian white-tailed deer Blue heron nesting Grassy, Russian & Seal Islands are swan concentration areas.	
35-38	WA	Tenasillahe Is.	0-5 6-15 16-25	Low ? ?	Riverine Exploration by seismic techniques Development could lead to contaminants reaching the river. Riparian Exploration by seismic techniques and drilling.	C. white-tailed deer N.W.R includes Tenasillahe Island but not Puget Island	C. white-tailed deer Waterfowl Canada geese & widgeon wintering area	Oregon does not allow drilling through water. Tenasillahe Is. is zoned conservation in CREST plan and is a Wildlife Refuge

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Table 6-2. Continued.

River mile	State	Facility/site	Probability		Projected sources of environmental impacts	Environmental concerns		Comments
			Yrs.	level		Areas	Species	
38-46	OR	Puget Island possible natural gas reserves				Elochoman River Hatchery	C. white-tailed deer Waterfowl & Great Blue Heron nesting on Puget Island Welch Island Heron Colony	Puget Is. is zoned Rural in CREST plan
40 42-49	WA OR	Oil and gas lease areas	Exploration 0-5 6-15 16-25	 high ? ?	RIPARIAN Slant drilling seismic work and if oil and gas is developed, pipelines, wells, pumping stations, and storage tanks RIVERINE No impact (assuming no drilling through water)	Near Columbian White-tailed Deer N.W.R. Great Blue Heron colony on Ryan Island Natural area- Kerry Island (in Westport Slough) Bird concentration area on south end Puget Is. NMFS research station juvenile salmon feeding area, commercial salmon fishing areas Wallace Island (natural habitat) WA State Hatchery in Beaver Creek	Columbian white-tailed deer Great blue heron Waterfowl Salmon Columbia white-tailed deer Ducks and geese rest in slough Bald eagle feeding	Additional areas further inland are also leased in both states
40	WA & OR	BPA upgrade of transmission line river crossing 115 kV	0-5 6-15 16-25	high low none	RIPARIAN/UPLAND Enlarge substation	Bald eagle feeding and great blue heron nesting near northern end of Puget Island	Great blue heron Bald eagle	Birds may collide with existing powerline
					RIVERINE Line could be buried--dredging impacts along shore and in channel	Juvenile salmon feeding near Oregon shore Commercial salmon fishing in channels on both sides of Puget Island	Salmon	No bird mortality if power lines are buried Dredging may damage salmon habitat
50	OR	Gas pipeline from Mist Fields to Northwest Natural Gas 16" pipeline near Clatskanie	0-5 6-15 16-25	low medium low	UPLAND 12" line was recently installed, but may need to install additional line or enlarge it	Natural area (Anunde Island) identified by Nature Conservancy (near Clatskanie)		Near but not at the Columbia River Estuary
54	OR	Port Westward Combined Cycle Power Plant 2 turbines (614MW) (oil or gas fired)	existing facility		RIPARIAN About 200 acres utilized, burns mostly gas (clean combustion) Backup facility- comes on line for power peaking or when Trojan nuclear plant shuts down	Marsh area in Bradbury Slough and Crims Is. Juvenile salmon feeding north Crims Is. (River Mile 54.5) Park on WA side (River Mile 52)	Salmon	
					RIVERINE Water usage for steam and cooling			
54 to 55-1/2	OR	Combined cycle 1200MW addition (4 additional turbines)	0-5 6-15 16-25	low medium medium	RIPARIAN & RIVERINE Same as for existing facility, but additional land affected	Same as for existing facility	Salmon	Site already used for same type facility (see above)

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Table 6-2. Continued.

River mile	State	Facility/site	Probability		Projected sources of environmental impacts	Environmental concerns		Comments
			Yrs.	level		Areas	Species	
54 to 55-1/2	OR	Coal Gasification Facility to supply medium BTU gas for Port Westward Combined Cycle Generating Facility	0-5 6-15 16-25	low medium medium	RIPARIAN Unit trains deliver coal Coal storage sites Solid waste disposal sites RIVERINE Process water, cooling water, leachates from solid waste, disposal sites & coal piles	Same as for existing combined cycle generating facility at the site	Salmon	Gasification process removes sulfur, so combustion is cleaner than for coal
54	OR	Other potential developments for transportation or processing, including oil, LPG, coal	0-5 6-15 16-25	low medium low	RIPARIAN Land requirements may vary, but is available. Area already partially developed. RIVERINE 1,250-foot dock can already handle vessels with 40 foot draft. Also have a 70'x70' barge dock. Site has channel access	Same as for existing combined cycle generating facility at the site.	Salmon	
54	OR	Other potential developments for transportation or processing, including oil, LPG, and coal	0-5 6-15 16-25	low medium low	RIPARIAN Land requirements may vary, but are available, area already partially developed RIVERINE 1,250-foot dock can already handle vessels with 40 foot draft. Also has a 70'x70' barge dock. Site has channel access	Same as for existing combined cycle generating facility at the site	Salmon	Port of St. Helens owns land, but Portland General Electric leases it. Some type of development will happen. Colocation with other energy developments may be desirable
57-60	WA	?	0-5 6-15 16-25	low low low	RIPARIAN Construction related impacts assumed	Fisher Island west end (great blue heron colony)	Great blue heron	Port of Longview owns and wants to develop. However, the development need not be energy related
					RIVERINE Marine transportation related impacts	Fishing sites near shore & commercial fishing in channel	Salmon	
62.6	OR WA	Overhead transmission line crossing		existing	RIPARIAN Land used for transmission towers and access roads	Walker Island and Lord Island are resting and breeding sites for Canada geese Sloughs at downstream end of Dibble Is. periodically used by mallards and Canada geese	Canada geese	Collisions of birds with wires
					RIVERINE None			

(continued)

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Table 6-2. Continued.

River mile	State	Facility/site	Probability Yrs.	Probability level	Projected sources of environmental impacts	Environmental concerns: Areas	Environmental concerns: Species	Comments
64-66	OR	Port of St. Helens sites for a small refinery and a petrochemical (ammonia) plant	0-5 6-15 16-25	medium medium medium (highly probable site will be developed for something even if not energy project)	RIPARIAN Site was used for fill from Mt. St. Helens dredge material Pipelines - 1 mile long Transmission lines- 1 mile long Air emissions 250 acres of land used for processing units, tanks, pump station and RR siding	Cowlitz Co. natural area between confluence of Cowlitz River and Carrols Channel about 3 miles N.W. across the river	Bald eagle nesting adjacent to river 2-3 miles east of site and 2-3 miles west of site Canada geese nesting to east and on Lord Island west of site	Support Facilities are close by Support Requirements include: 5,000 b/d of oil or $33\text{x}10^6\text{ft}^3$ gas, or 10MW electricity, use of RR for construction, oil pipeline to site may be built (river crossing)
					RIVERINE Limited dredging Water usage 50,000 b/d with once through flow and discharge of 45,000 b/d, or water usage of 100,000 b/d assuming cooling tower used Heated water discharge to river Increased shipping Docks needed Waste discharge (NPDES permit) Possible oil or chemical spills	Commercial fishing in channel Cowlitz River is channel for debris from Mt. St. Helens eruptions Channel maintenance dredging is compounded	Bald eagle feeding along river 2-3 miles to the east Salmon	
66	WA	Port of Longview Calcine Coke Shipment Facility (marine terminal) 150,000 tons/yr.	0-5 6-15 16-25	high high high	RIPARIAN Site already developed as a terminal. Need a little more storage space. Material shipped by rail to site	Cowlitz Co. natural area about 2-3 miles east of site	Bald eagle nesting adjacent to river 2-3 miles east of site and 3-4 miles west of site Canada geese nesting to east and on Lord Is. to west of site	Impacts mostly upland habitat beyond scope of this project
					RIVERINE Dock already in. Marine Terminal Impacts 10 to 15 vessels/year	Cowlitz River is channel for debris from Mt. St. Helens eruptions Maintenance dredging is compounded by the volcano. Commercial fishing in channel State Fish Hatchery up Cowlitz River	Bald eagles feed along river to the east Salmon	
65-66	WA	Oil & Gas storage facilities		existing	RIPARIAN Already developed, possible spills RIVERINE Spills could enter water	Same as above	Same as above	
Longview Ranier	WA OR	Various			Secondary developments from increased work force in these areas			

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Table 6-2. Continued.

River mile	State	Facility/site	Probability		Projected sources of environmental impacts	Environmental concerns		Comments
			Yrs.	level		Areas	Species	
68- 71-1/2	WA	Cottonwood Is. LNG/LPG Terminal or	0-5 6-15 16-25	Low Low Low	RIPARIAN - LNG/LPG Area already filled with Mt. St. Helens debris Fire and explosion hazard (siting would affect risks of Trojan nuclear plant at River Mile 72)		Purple martin	Cumulative probability of some development is 0-5 yrs - medium; 6-15 yrs - high; 16-25 yrs - high
		Coal Terminal or	0-5 6-15 16-25	None Low Low	RIPARIAN - Coal See impacts for Tongue Pt. Coal Terminal, River Mile 18. This development unlikely as Kalama has competitive one			Site has sufficient area and channel frontage to allow three developments
		Refinery/ Petrochemicals/ Synfuels	0-5 6-15 16-25	Low Low Low	RIPARIAN - Refinery etc. See impacts for Port of St. Helens at River Mile 64-66			Site has also been filled, largely with dredge spoils from the debris of Mt. St. Helens eruption which filled the Cowlitz River and the Columbia River Channel
					RIVERINE - all Pier construction Some dredging Rail, power and road crossings of Carrolls Channel to reach island site	Cowlitz County Natural area Carrolls Channel Salmon fishing in channels State Fish Hatchery up Cowlitz River		
72	OR	Trojan nuclear power facility and submerged power line crossing		existing	RIPARIAN Construction on bedrock Minimal change on runoff landscaping created aesthetically pleasing lake, upland and shoreline	Carr Slough natural area designated by Nature Conservancy Wetlands used by waterfowl and hunters	Rare plants (WAPATO) Whistling swan Geese Ducks	Impacts of new facility would be very similar to existing facility
		Proposed second facility	0-5 6-15 16-25	None None Low	Slight salt drift from cooling tower Risk of radioactive releases Land area covered by structures			
					RIVERINE Dredging impacts, water consumption heated discharge, chemicals and radioactivity discharged	Salmon fishing & warm water fishing areas	Salmon	
72-1/2	WA	Kalama Coal Terminal 175 acre coal storage enclosed by double track RR loop.	0-5 6-15 16-25	High (constr.) High (operation) High (operation)	RIPARIAN 1-2 unit trains/day at start increasing to 4-5/day at capacity. Site already filled with Mt. St. Helen's debris. Coal dust emissions (150 tons/year)	Carr Slough natural area identified by Nature Conservancy (across river)		Draft EIS filed in June 1981 Will probably pre-empt coal terminal on Cottonwood Island
					RIVERINE 6-7 ships/week 3 piers offshore No dredging NPDES discharge (treated runoff from coal piles)	Salmon fishing in channel Salmon hatchery upstream	Salmon	

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Table 6-2. Continued.

River mile	State	Facility/site	Probability Yrs.	Probability Level	Projected sources of environmental impacts	Environmental concerns Areas	Environmental concerns Species	Comments
73	WA	Hydro diversion dam on Kalama River about 13 miles upstream from the Columbia. Slight impoundment (10' high dam)	0-5 6-15 16-25	None Low Medium	RIPARIAN Some inundation Construction impacts Diversion tunnel or pipeline			Listed as an active site on the Corps of Engineers inventory
					RIVERINE Flow on about 12 miles impacted by diversion (perhaps blocked)	Spawning beds? State Salmon Hatchery	Salmon	
73-74	WA	Industrial filled site, non-specific development	0-5 6-15 16-25	Low Medium Medium	RIPARIAN Unknown	Carr Slough natural area across river Sandy Island (great blue heron colony)	Great blue heron	
					RIVERINE Probable pier	Salmon hatchery upstream Commercial fishing in Channel	Salmon	
74	WA	Kalama Chemical (phenol production)	existing		RIPARIAN Additional structures on already impacted site	Sandy Island (great blue heron colony)	Great blue heron	
		Possible expansion	0-5 6-15 16-25	Medium Low Low	RIVERINE Increase in shipping by boat or barge Potential for spill of toxic materials or wastes	Commercial fishing grounds Salmon Hatchery upstream	Salmon	
76-1/2	WA	Kalama Chemical	existing facility		RIPARIAN	Deer Island is important habitat to many animals	Great blue heron Deer Canada geese Waterfowl Possible tern colony at north end of Sandy Island	
					RIVERINE Treated waste discharge Possible toxic spill Shipping impacts			
77		Submarine crossing of 16" gas pipeline	existing pipeline		RIPARIAN None	Deer Island	Canada geese & widgeon overwintering area on Deer Island	Facility in place
					RIVERINE Risk of breakage from: Earthquake Vessel anchor			
80	WA	Martin Island LPG/Synfuel/Petrochemical	0-5 6-15 16-25	? ? ?	RIPARIAN Fill needed	Martin Island, Deer Island (to west) and Burke Island (to south) are important habitat to bird and mammal populations	Great blue heron Canada geese Deer Waterfowl	
					RIVERINE Piers, crossings (road, rail, pipeline & power) to mainland and waste discharge Risk of spills	River channel Warm water fish in sloughs between islands	Salmon	

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Table 6-2. Continued.

River mile	State	Facility/site	Probability		Projected sources of environmental impacts	Environmental concerns		Comments
			Yrs.	Level		Areas	Species	
81	WA	Burke Island Biomass Conversion (alcohol plant) Synfuel/LPG	0-5 6-15 16-25	? ? ?	RIPARIAN & RIVERINE Same as for Martin Island above (River Mile 80)	Island is important to bird and mammal populations, as are Martin Island (to north) and Deer Island (to west) River Channel- Commercial fishing Sloughs- Warm water fish	Canada Geese Waterfowl Deer	
81	OR	South End of Deer Island-petrochemical or refinery	0-5 6-15 16-25	None Low Low	RIPARIAN & RIVERINE Same as for Martin Island above (River Mile 80)	Same description as for River Mile 80, WA.	Same as for River Mile 80, WA.	
82	OR	Reichold Chemical Co. Fertilizer (Natural gas feedstock)		existing facility	RIPARIAN Already impacted	Near Deer Island	Great blue heron Canada geese Deer Widgeon & Canada geese overwintering area	
					RIVERINE Cooling water Process water Waste discharge			
82	OR	Reichold Chemical Co. expansion of existing facility	0-5 6-15 16-25	Medium High High	RIRARIAN Clearing or filling construction impacts Spill risk	Near Deer Island and Burke Island	Great blue heron Canada geese Deer	
					RIVERINE Marine traffic increase. Spill risk Piers Cooling & process water Waste discharge	River channel	Salmon	
82	OR	Petrochemical/ LPG/Refinery	0-5 6-15 16-25	None Medium Low	RIPARIAN Clearing and filling Construction impacts Spill risk Fire risk (LPG)	Near Deer Island and Burke Island	Great blue heron Canada geese Deer	
					RIVERINE Increased vessel traffic Increased spill risk Pier Cooling & process water Waste discharge	River channel	Salmon	

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Table 6-2. Concluded.

River mile	State	Facility/site	Probability		Projected sources of environmental impacts	Environmental concerns		Comments
			Yrs.	Level		Areas	Species	
87		Submarine pipeline crossing		Existing facility	**RIPARIAN** None	Ridgefield Natural Wildlife Refuge (WA) Sauvie Island Wildlife Management Area	Sandhill crane (rare bird)	Flow alteration only significant impact
					RIVERINE Pipeline damage by earthquake, and dragging anchors	Wapato Natural Area High concentrations of Canada geese, mallards, pintail & widgeon on Ridgefield NWR & Sauvie Island WMA	Wapato area (untouched)	
87	WA	Lewis River Second Power House at Lake Merwin (16 mi. upstream)	0-5 6-15 16-25	Low Medium Medium	**RIPARIAN** Some construction impacts		Large heron colony (555 nests) on Bachelor Island	
					RIVERINE Flow will be altered	Fish spawning beds on Lewis River State Fish Hatcheries		
87	WA	East Fork of Lewis River 10' diversion dam (about 14 mi. upstream) 26.8MW capacity	0-5 6-15 16-25	None Medium Medium	**RIPARIAN** Minor Inundation Construction impacts Diversion tunnel or pipeline			Flow alteration very significant
					RIVERINE Flow diminished or halted for 6 miles of stream	Fish spawning beds on Lewis River		
100.5		Submarine Pipeline Crossing		Existing	**RIPARIAN** None	Shillapo Wildlife Recreation Area 2 miles North	Waterfowl	
					RIVERINE Risk of pipeline failure: earthquake, vessel anchor		Sturgeon Salmon	
102	OR	North end of Pearcy Island-Coal terminal	0-5 6-15 16-25	None Medium Medium	**RIPARIAN** Fill Altered drainage Dust Large storage areas Unit train deliveries	Hayden Island to southeast	Waterfowl wintering over	Similar to impacts at Kalama or Tongue Point, but vessels have further to travel
					RIVERINE Increased vessel traffic Waste discharges (NPDES permit) Piers		Salmon Sturgeon	

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dredging program of the U.S. Army Corps of Engineers has a significant cumulative impact, in that much of the channel habitat is deeper than the natural condition, and is periodically disturbed by dredging.

The most significant cumulative impacts that may result from the future energy developments, as presented in Table 6.2, will be the additional loss of fish habitat from small hydropower developments on the lower tributaries, and from continuation of, and perhaps increasing, the channel dredging programs. Wetlands that will be committed to energy developments in the estuary will be mostly on the Oregon side for either OCS support or coal transshipment. These developments are contingent on nearby OCS development and other coal terminal developments further up the river. Many developments which may come about in the future, are targeted for areas that are already developed to some degree, which should reduce the potential land commitments that may otherwise be required. Specifically, developments near Longview, Port Westward, and Rainier seem likely, and are in areas which already have similar development.

Most all energy developments will result in increased shipping, which increases the risk of vessel accidents resulting in oil spills.

6.3.1 Estuarine Hydrology

Developments will increase local surface runoff from impervious surfaces and compacted sites, especially during storms. Heavy storm flows influence downstream channels, banks, and sloughs. Dams, however, serve to decrease peak flows.

The possibility of disruption to subsurface flows and water tables presents another cumulative impact. Many energy developments require large quantities of fresh water, thus depleting existing reservoirs and distribution patterns. In the water-rich Pacific Northwest, this is of less concern than in other parts of the country.

The main stem flow of the Columbia River is highly regulated by existing dams. Energy developments, especially numerous small hydro projects on the tributaries will regulate local flows with additional impacts. The creation of backwater dams will store water during high flow and distribute it more evenly over longer periods, thereby reducing rapid fluctuations in downstream flows. These modifications will substantially alter fish breeding and rearing habitats, as well as reduce the width of the riparian habitat. Each new hydropower project on a tributary will reduce fish populations because of loss of habitat and/or blockage of migratory paths.

Regulation of tributary flows will reduce many of the riparian, riverine, and estuarine communities that were adapted to the local, natural flow regime. The riparian, riverine, and estuarine communities of the Columbia River proper and most of its estuary are already adapted to the regulated flow of the Columbia River.

Dredging of new channels, deepening and widening of existing channels, maintenance dredging, and dredging for site preparation and commercial activities will lead to changes in estuarine circulation, which in turn will affect sediment transport processes, salinity distribution, and biological communities.

6.3.2 Water Quality

Dredging will also influence water quality, both in the short- and long-term. Short term impacts of dredging may include lowering of dissolved oxygen, increase of turbidity, release of oils and grease, and release of priority pollutants. Long term water quality changes resulting from dredging include increased salinity intrusion, localized changes in residence time with possible effects on temperature, or biological processes which may change the nutrient distribution. For the most part, the sediments dredged from the Columbia River are relatively clean, and the natural flushing action of the estuary, given the tremendous flow of the river, make the impacts of dredging on water quality noncumulative. However, projected salinity increases of 2 ppt (Vorderstrasse 1980) from deepening and widening the channel over the Columbia River entrance bar, for example, although not predicted to have many direct effects on species of concern, may have an effect on invertebrates and other food chain species. Clearly, the cumulative impacts would be expected to result in a redistribution of estuarine and marine animals and aquatic plants.

6.3.3 Thermal Effects

Many energy generation and fuel processing facilities require cooling waters and discharge warm waste water downstream. Warmer water temperatures may also be expected from water released downstream of small hydro projects. Lake waters behind these dams form solar sinks. This problem is already highly evident in the Columbia River from the main stem dams. In general, there has been an increase in temperatures in the entire river system (Moore 1968), and it may be expected to increase with construction of new energy facilities. This manifests itself in salmon migration impedance and displacement of fish by species more tolerant of warm water, such as carp.

There is a loss of freshwater to the system from evaporation from the larger surface area reservoirs and also from energy development process waters (such as the Trojan Nuclear Power Plant, which evaporates water in its cooling system).

6.3.4 Air Quality Degradation

Energy developments adjacent to the Columbia River will result in a gradual decline in air quality over the estuary and indirectly influences regional water quality. Emissions of SO_x and NO_x may be converted to sulfuric, nitrous, and nitric acid, thus contributing to the acidity of regional rainfall. Acid rain lowers the pH of aquatic systems that have low buffering capacity, such as the alpine lakes of the Cascades. This problem has recently surfaced in the Pacific Northwest (Welch et al. 1981).

Damage to fish populations is the main concern related to acid precipitation in the northwest and the Cascades (Hendrey et al. 1976; Glass 1978; Fritz 1980). However, changes in aquatic organisms, including microdecomposers, algae, and microphytes also occur (Hendrey et al. 1976; Glass 1978) and result in changing feeding relations and subsequent community composition.

Acidification has also been implicated to influence vegetation. Nutrient cycling processes in forest soils may reduce long-term productivity (Tamm 1976). A possible mechanism for dredging includes acid inhibition of nitrogen-fixation by free-living bacteria, decreased soil respiration, increased nutrient leaching, and changing availability of nutrients, cations, and heavy elements (Malmer 1976; Tamm 1976; Glass 1978). An excellent review of acidic precipitation and its consequences for aquatic ecosystems is presented by Haines (1981).

6.3.5 Reduction in Biological Communities

All types of development will remove or significantly alter some of the habitats in the study area. The total acreage of estuarine and riparian habitat will decrease with increasing energy and nonenergy related development. The larger changes will result from inundating river valleys for reservoirs, acreage required for transmission lines and pipeline construction and maintenance, shoreline development, and land required for disposal sites of dredged materials, sludge, and ash. Riparian habitat will be reduced and fragmented by the projected energy-related developments.

CHAPTER 7.0 GENERIC ENERGY FACILITY ORIENTED MANAGEMENT AND MITIGATION

Specification of mitigation measures for the impacts of energy related development in the Columbia River Estuary depends directly upon the specificity and quality of information available on the impacts themselves. Two difficulties arise immediately. First, the nature and magnitude of impacts and, hence, the type and degree of appropriate mitigation, depend to a very large extent upon the particular, site-specific, microclimatic and microenvironmental features of the location in which a given development occurs. Second, the uncertainty of both magnitude and significance of impacts is often very high, so that, although the kinds of possible effects of a project may be postulated, the degree of impact and resultant need for mitigation (or even ability to mitigate) has not been well defined in the literature.

Uncertainty is greatest in respect to those chronic, low-level, and cumulative effects which are most likely to represent the bulk of a given facility's impact on its local environment. The relatively exceptional, commercially important, highly visible, or disastrous acute effects of an energy facility have received more attention, have usually been more amenable to measurement, and hence are generally better known. Mitigation techniques for these effects are frequently advanced to the extent that state-of-the-art technology may be cited.

Major sources of uncertainty in predicting environmental impacts have been summarized by the National Research Council (1980) and include lack of information on: effects of long-term, low-level effluents; energy and nutrient needs of organisms (limiting factors); synergistic effects in both chronic and acute exposures; ecosystem response to acute stress; stability indicators and correlates of stability; population and environmental fluctuations; ecological-meteorological interactions; microbial ecology and nutrient chemistry; relation of gross effluent levels to levels experienced in the microenvironments of living organisms (especially considering behavioral response); genetic parameters governing response to stress; and cumulative effects of successive small habitat losses on populations.

With regard to the last item on the foregoing list, it is the opinion of the National Research Council (1980) that "...The most serious ecological losses imposed by energy related activities arise from the cumulative effects of small habitat losses, rather than from spatially and temporally isolated, easily visible catastrophic events." A general policy of extensive compensatory habitat enhancement may therefore be the single most effective mitigation alternative available to the USFWS.

Given the foregoing context of uncertainty in defining impacts and therefore mitigation, it is the purpose of this chapter to summarize generic mitigation measures which may be applied to ameliorate impacts of projected energy related development on fish and wildlife in the Columbia River Estuary. No attempt is made to endorse best available mitigation measures. For the purposes of this chapter, mitigation is defined according to the Council of Environmental Quality (CEQ) regulations published in the Code of Federal Regulations (CFR). This definition distinguishes five stages of mitigation: 1) avoidance; 2) minimization of effects during construction; 3) minimization of effects during operation; 4) restoration of the affected environment; and 5) compensation.

7.1 FACILITY SITING

Facility siting can play an important role in minimizing impacts from energy development. Therefore, many impact assessments require a site-specific evaluation. The permit and licensing process associated with siting of a major facility emphasizes identification of the project impacts and determination of appropriate mitigation measures. The requirements of the State Environmental Policy Act (SEPA), the National Environmental Protection Act (NEPA), FERC, and the Energy Facility Site Evaluation Council (EFSEC) provide the permit guidelines which lead to the identification of impacts and mitigation measures. Consideration of alternative sites is another important aspect of these permit and licensing processes and should be utilized as a mitigation measure.

For siting to be an effective mitigating measure, the relative environmental consequences of all potential sites must be compared with the relative economic and social implications of use of these same sites. Such a comparison should be performed by surveying all potential sites over the entire siting domain at a level of detail sufficient to: 1) identify the relative environmental consequences of the use of one site over another, and 2) winnow down the entire siting domain to a few sites for which more intensive investigations may be required (Palmer and Grove 1980). In practice, this seldom, if ever, occurs. Rather, the economic factors of plant siting drive developers to preferred sites, and evaluation of site alternatives in environmental impact statements consists of putting forth one or two sites of industry choice, surrounded by a cluster of less appropriate sites which are not at all comparable (Palmer and Grove 1980).

Although it is easy to fault the site evaluation process for its ineffectiveness as a mitigation tool, it must be recognized that the acquisition and maintenance of a comprehensive data base sufficient to the task should not be an industry function, and because of its total scope, may well be impractical or impossible for even state or federal agencies. Certainly this document does not pretend to fulfill such a function for the lower Columbia River and Estuary. A comparison of energy facility development sites requires an assessment beyond the geographic scope of this report's study area, as many facilities are not totally dependent on siting near water. Regionally, a specific type of facility somewhere in Puget Sound may be preferable over one on the Columbia River, but such a facility would not meet the goals of a port district desiring expansion on the

Columbia River or those of an underemployed work force. The competitive nature of different ports encourages an economic competitiveness while discouraging an equal treatment of the environmental aspects of site selection. Political processes, imprecise at best, will further influence the siting process.

Regardless, facility siting remains the most crucial aspect of any energy related activity along the Columbia River. Management and mitigation for facilities within a complex environment, such as that of the lower Columbia River, must be site specific because the site chosen will largely determine the types and severity of all impact and the degree to which they can be mitigated.

7.2 FACILITY CONSTRUCTION

The environmental effects of construction and operation must be described as required by Section 102 (2)(C) of the National Environmental Policy Act of 1969 (Pub. Law 91-90, 83 Stat. 852) before permits, grants, licenses, etc. can be issued. Specific procedures for the preparation of an Environmental Impact Statement (EIS) for energy facilities are published by the CEQ (38FR20550) and the U.S. Department of Interior (USDI 1976).

7.2.1 Construction in Terrestrial Habitats

Primary mitigation measures during construction of energy facilities in terrestrial habitats include: 1) controlling soil erosion, 2) appropriately scheduling construction activities, 3) revegetation, 4) minimizing the duration of construction, 5) minimizing obstruction to movement of fish and wildlife, 6) maintaining air quality, 7) controlling the use of toxic and hazardous substances, 8) maintaining water quality, 9) minimizing habitat loss, 10) minimizing noise, and 11) managing construction personnel.

The potential for soil erosion and subsequent siltation and sedimentation can be minimized by restricting vegetation removal, drainage alteration, and surface disruption. Numerous cost effective control techniques should be employed during the construction phase of a project. These measures include, but are not limited to, construction of sediment catch basins, storm drains, graded berms, filter berms, water bars, energy dissipators, swales, and drainage culverts (Thronson 1971; USEPA 1972; Burroughs et al. 1976; Dallaire 1976; DFOC 1978; CDC 1978). Practices such as hand clearing vegetation rather than using heavy equipment, using the lightest equipment to get the job done, and scheduling major earth work during the dry season can also help reduce soil compaction and erosion (CEC 1981). Construction of roads can cause severe erosion problems. Road design and mitigation techniques are described by Burroughs et al. (1967), USEPA (1972), Lysons and Wellburn (1976), and Washington Forest Practice Board (1976).

Major construction activities should be scheduled to avoid sensitive and critical periods for fish and wildlife species inhabiting areas in and adjacent to a project site. For example, construction should be minimized during breeding season for bald eagles, especially during early nesting phenology (Call 1978), and during the migration/spawning period for anadromous fish occurring in waterways traversing construction sites. Movement periods for waterfowl and large mammals and the nesting/denning periods for avifauna and furbearers should also be considered when scheduling construction activities. PNRC (1975) and Tabor et al. (1980) have established critical periods of use for wildlife groups of the Columbia River.

Promote revegetation of all exposed surfaces as soon as construction activities and natural factors will permit. Revegetation can be facilitated by storing and reusing excavated topsoils, by using fertilizers (Taber 1977), and by employing seedbed preparation measures and minimal surface disturbance reseeding techniques (e.g., seed drills). Netting and hydromulching can be used to initially stabilize reseeded surfaces. Appropriate revegetation goals may be rapid soil stabilization and eventual return to predevelopment species composition. Revegetation schemes should also include enhancement of food and cover resources for fish and wildlife (Egler 1957; USDA 1969; Bates et al. 1978; Merker and Hale 1980). Priority should be given to revegetating and enhancing all disturbed riparian areas.

The length of the construction period should be limited to the extent possible. Construction of linear projects such as roads, pipelines, and power transmission lines should progress in short intervals thus minimizing the length of time that disturbance will occur in a given area. Crossing aquatic habitat is of critical concern. Publications by McCellan (1970) and the Department of Fisheries and Oceans, Canada (DFOC 1978) address various types of culverts and pipeline crossing techniques.

Construction projects disrupt normal daily and seasonal movements of fish and wildlife and create numerous hazards causing increased mortality. Many potential problems can be avoided by careful planning and siting, by appropriate scheduling, and by minimizing the duration of activities. Roads, railroads, canals, and pipelines should provide safe crossing passages for wildlife (Section 7.4.7 and 7.4.8). Fencing of ROW's and construction sites should be minimized; however, where fencing is necessary, it should meet proper specifications (Section 7.4.8). ROW fences, canals, and other structures that can trap wildlife should be equipped with one-way gates, escape ramps, or similar devices (Sections 7.2.2 and 7.4.8). Barriers temporarily blocking upstream migration of fish may be mitigated by constructing artificial spawning beds below the blockage (Section 7.4.1).

Maintenance of air quality during construction can be achieved through proper disposal of combustible debris, control of vehicle emissions, and minimizing dust. Burning can be minimized by recycling appropriate materials for mulch and landfill, and by incorporating these into associated projects such as habitat enhancement for fish and wildlife and recreational facilities. Burning of the nonrecyclable debris should occur only on authorized days. Dust can be minimized by enforcing reasonable speed limits (20 mph); critical areas can be sprinkled with water and stabilized using structural (pavement or oil-binding agents) and nonstructural (vegetation) measures.

Toxic and hazardous chemicals and sewage should be stored and disposed of at authorized sites in compliance with OSHA regulations. Sites should be located away from streams (i.e. outside the 100 year floodplain) and groundwater bodies. Recycling of chemicals should be encouraged to the extent possible. Contamination by these substances can be minimized by restricting transportation and transfering chemicals (including equipment refueling) to designated sites that are protected by structures such as containment berms. Use of chemicals should be minimized, especially if construction activities occur in riparian zones.

Detention ponds and ditches which may contain hazardous chemicals should be appropriately fenced to restrict entry by terrestrial wildlife including burrowing animals. If sizeable persistent ponds are associated with energy facilities (e.g. evaporation ponds), methods should be employed to deter avifauna from entering polluted areas. A thorough review of deterrent methods for avifauna and their effectiveness is found in Koski and Richardson (1976).

Construction activities involving dredging operations should be preceded by chemical analysis of sediments to determine potential toxic and hazardous contaminants. Dredging equipment that minimizes sediment disturbance and is equipped with silt screens should be used. Dredge spoils containing toxic and hazardous substances should be properly disposed of at approved sites (Barnard and Hand 1978; Gambrell et al. 1978; Haliburton 1978). Specific measures pertinent to dredging operations are discussed in Section 7.3.2.

Water quality can be maintained by mitigation measures that control soil erosion by containment and disposal of toxic and hazardous chemicals and wastes, and by actions that deal with careful timing of construction. Other actions should include proper installation of stream crossings, temporary stream diversions that maintain normal flow regimes (Bell 1973; Watts 1974; Evans and Johnston 1976), excavation of sediment from accumulation areas, and minimizing construction activities in riparian zones. Favorable water temperatures for aquatic organisms should be maintained by preserving normal flow regimes and riparian vegetation (Brasier and Brown 1973; USEPA 1973a; Gillick and Scott 1975; DFOC 1978).

Methods for filtering and detaining runoff water from large impervious surfaces such as parking lots and storage yards are discussed in Thronson (1971), USEPA (1972), and ASCE (1977). These methods generally promote infiltration of water and help recharge groundwaters. Three types of porous pavements have been developed that allow direct infiltration of water.

To prevent avoidable habitat loss several measures should be taken. Storage of construction materials should be within well defined site boundaries. Excavated materials such as sanitary dredge materials should be recycled for construction of structures and should be used in conjunction with associated mitigation actions, for example, subimpoundment dikes and berms (Eng and Childress 1977). Construction ROW's should be minimized and when possible restricted to habitat of lowest productivity, sites previously disturbed, and areas sited for future disruption (e.g., inundation basin related to a dam project) (USFWS 1981).

The revegetation of all nonessential roads and closing of public access to roads which traverse critical habitat for wildlife is desirable (Goodwin 1975; Perry and Overly 1977; Ward et al. 1980; USFWS et al. 1981).

Appropriate timing of construction activities can alleviate most adverse effects of noise on wildlife. All equipment should have OSHA standard mufflers and spark arresters. Blasting operations should proceed using the minimum charge required. Blasting mats constructed of wire mesh, tires, or logs can reduce the danger of rock throw (Nichols 1962).

Construction personnel should be educated on the adverse effects of uncontrolled ORV activities, handling and working with toxic chemicals, careful excavation practices, fire prevention, and initial fire suppression techniques. Workers should be prohibited from the construction site during nonworking hours; domestic pets and ORV use should not be allowed onsite. Construction activities should be carefully monitored (e.g., by USEPA 1976 standards) and closely supervised throughout the duration of work on the project. Mass transit should be provided for construction personnel.

7.2.2 Construction in Aquatic Habitats

The majority of mitigation measures outlined in Section 7.2.1 for construction in terrestrial habitats also apply to construction in aquatic habitats. Paramount among these measures are avoidance and minimization of impacts through appropriate timing of construction activities and by reducing the duration and extent of activities. For example, the significance of impacts due to blasting in aquatic systems can be greatly diminished simply by avoiding the time when anadromous fish and their eggs are present. Other categories of concern to which mitigation should be targeted include: 1) controlling turbidity and sedimentation, 2) maintaining riparian habitat, 3) maintaining water quality, and 4) minimizing effects of blasting operations. An overview of some basic impacts and mitigation measures are discussed by Bell (1973), USEPA (1976b,c), USDA (1978), and USFWS (1978a).

Increased turbidity and sedimentation are of special concern because they can have deleterious effects on a broad spectrum of aquatic organisms, as discussed in Section 3.2.2.2.1, and because they occur during all types of construction projects (Fredriksen 1970). Careful construction techniques used in conjunction with preventive measures, such as the use of silt screens on dredging equipment, may reduce sedimentation. Downstream sediment traps and catchments can be employed to prevent accumulation of deposits in critical areas. Mitigation associated with dredging processes are discussed in Section 7.3.2.

If silting does occur in anadromous fish spawning habitats several alternatives, outlined by Wilson (1975), Mih (1976), USFWS (1978a) and Mih and Bailey (1979), are available to restore these sites or compensate for reduced productivity. Alternative actions include: replacement of gravel, resuspension of fine material using mechanical means, removing sediments using a flushing and suction machine (riffle sifter), construction of artificial spawning channels, and altering existing channels (irrigation canals, etc.) to serve as spawning habitat.

Riparian habitat can be severely damaged as a result of construction projects in aquatic areas. Removal and degradation of the riparian vegetation can destabilize streambanks, disrupt travel corridors for birds and mammals, and deteriorate water quality by increasing water temperature and sediment loads. These potential hazards can be lessened by using, to the extent possible, direct human labor rather than heavy equipment, centering activities and access routes at aquatic sites where they will be least damaging, stockpiling debris on only one side of the waterway at any given location (McConnell 1979), and rapidly reestablishing vegetation. Tabor et al. (1980) recommend grading of disturbed or unproductive shorelines to produce gradual slopes or terraces.

Restabilization of streambanks may require temporary or permanent use of structures such as riprap, gabions, log rafts, and offshore breakwaters to reduce the potential for erosion (USDA 1969; USFWS 1978f). Many of these techniques may be effective for bank stabilization, but can also restrict access to waterways by wildlife and, hence, should not be employed.

Emphasis should be to stabilize streambanks using vegetation or a combination of vegetation and structural work rather than structural work alone (Lines et al. 1978). Stabilization efforts must include maintenance of a buffer strip using fences to protect the area from grazing by domestic livestock but allowing access by wildlife (USFWS 1978f; Kerr 1979; Yoakum et al. 1980). An erosion management plan for the Chehalis River, Washington (Grays Harbor Regional Planning Commission 1974) discusses the implementation of many of these methods.

Considerable effort should be expended to maintain and rehabilitate riparian habitat along all waterways. Where this is not possible and cement lined streambanks and canals are necessary, nonhazardous crossing accompanied by appropriate fencing, escape ramps, one-way gates, and warning devices should be provided (Latham and Verzuh 1971; Seaman 1977; USFWS 1978; Guenther et al. 1979).

A number of precautionary measures should be taken to reduce unavoidable damage resulting from construction in wetlands. These measures include using the lightest possible equipment to complete construction and operating machinery from mats or other devices that distribute the load, thus minimizing disruption of the substrate (USEPA 1976b). If canals are dug in floodplains they should be properly filled and revegetated or equipped with gates that allow the natural influx of fresh- and saltwater.

Mitigation measures addressed above should help to ensure that water quality is maintained. However, among the greatest potential threats to water quality is the probability of contamination due to accidental spills of fuels, lubricants, and/or other hazardous substances. These impacts may in part be mitigated by conservative use of chemicals at construction sites, careful handling by properly trained personnel, and transfer, storage, and disposal of materials at authorized sites that comply with OSHA regulations. Toxic substances spill contingency plans and liability funds should be designed to assist in mitigating damage from possible spills. Construction personnel should be educated in initial containment procedures, and state-of-the-art containment and cleanup technology and equipment should be rapidly available in case of accidents.

Special consideration should be given to construction of pipelines that traverse aquatic ecosystems. Several alternative crossing techniques are available. Site-specific criteria must be used to evaluate the most appropriate method to be employed at a crossing. Traditional trenched crossings of marshes and streams generally cause the most severe damage to aquatic and riparian habitats and should not be used (San Francisco Bay Conservation and Development Commission 1974). Preferred alternatives include elevated or trench and push crossings for marshes, and suspended or bored crossings for streams.

Submarine pipelines laid across large bodies of water can be constructed primarily using two methods (Oceanographic Commission of Washington 1975). The pull method involves pulling the pipe from one shore, where pipe lengths are joined, across to the far shore. Most commonly the pipe is submerged as it is winched across. Alternatively, a positive buoyancy method is used to float the pipe and pull it across the surface of the water. The second method for constructing submarine pipelines is to use a lay-barge. Pipe lengths are joined and lowered to the substrate from the lay-barge as it moves across the body of water.

Where possible, submarine pipelines should be buried with at least 2 m (6.6 ft) of cover, and the pipeline crossing should be sufficiently marked to minimize the risks of anchors fouling the line. Pipelines should be constructed with an adequate cathodic protection system to reduce maintenance and the potential of pipeline failure due to corrosion. Further, cathodic protection systems and pipelines must be periodically monitored to assure they are in proper working order.

The use of slow velocity charges such as black powder can reduce lethal effects of blasting operations in aquatic habitats. Shock absorbent materials can be used to baffle and dampen shock waves in critical areas. Use of sediment traps and catchments can help reduce the surge of downstream sediments associated with aquatic blasting activities (Northwest Pipeline Corporation 1980).

7.3 MANAGEMENT AND MITIGATION OF COMMON IMPACTS OF ENERGY FACILITIES

7.3.1 Oil Spills

The main concern regarding an oil spill is the possibility of it entering the river or estuary. Oil spills on land are generally localized and of little impact (unless they contaminate a groundwater aquifer). When a spill occurs in the river or estuary, oil is rapidly transported by river flow, tidal flow, and wind driven surface currents, thereby reaching other habitats. Oil spills are damaging to habitats and species, the damage occurring from a combination of physical effects (i.e., coating, smothering) and toxic effects.

The intertidal habitats, flats, eelgrass beds, and marshes, are the most severely impacted by oil spills, and protection of these habitats is a high priority in mitigation and contingency planning. Birds are especially vulnerable to spilled oil, so waterfowl concentration areas are of high priority.

The relatively rapid flushing of the estuary, due to the combined effects of tidal exchange and large volume of freshwater flow, works to dissipate a spill, and is conducive to a relatively speedy recovery of those ecosystems impacted. However, the rapid flushing also means that containment of a spill requires a rapid coordinated response with sufficient equipment to protect numerous areas, while attempting to contain and recover the spilled oil. Such a task is difficult at best.

The probability of an oil spill increases with any increase in vessel traffic. Vessel traffic is tied to all types of trade and cannot be evaluated only on the basis of energy developments. Analysis of tanker spills on six river systems, including the Columbia River, yielded a probability of 0.000833 spills greater than 100 gallons per trip (OIW 1978a) (see Table 4-14).

Increased tanker traffic in the Columbia River and/or Estuary may result from refinery development, increased oil usage in the region, or OCS development (if OCS oil is piped ashore to ports in the estuary). Other vessel traffic may increase from other energy or nonenergy related developments.

A major spill affects fish and wildlife, especially if it occurs when species most susceptible to oil are present. This includes waterfowl, juvenile fish, and larval forms of marine, estuarine, and riverine species. Shellfish may become tainted by oil and lose their market value. While this may impact fishermen and recreationists who usually harvest that resource, the cessation of human consumption may benefit the species.

There is an abundance of literature on oil spills and their mitigation. Reports specific to the Columbia River and Estuary include "Oil Spill Cleanup Capabilities on the Columbia River Basin", by the OIW (1978a) and the "Oil Spill Contingency Plan for the Columbia River", prepared by Sutherland (1979) for CREST. Regulations addressing the prevention and mitigation of oil spills are found in several titles and subchapters of the CFR.

Loehr et al. (1978) summarized oil spill environmental protection measures for a proposed tanker, terminal, tank farm, and pipeline oil system. The coverage was generic, and the measures are largely applicable to mitigation of oil spills in the Columbia River and Estuary. These included identified preventive, mitigative, and contingency measures. Preventive measures were defined as those positive steps which may be taken to reduce the occurrence of spills and include personnel training, proper procedures, and equipment maintenance and inspections. Mitigative measures were interpreted by Loehr et al. (1978) to be those which are in place prior to a spill to prevent it from leaving the immediate vicinity and entering land or aquatic ecosystems (e.g., booms around vessels at terminals; ditches, dikes, and holding ponds around tanks). Spills escaping the in-place containment structures are brought under control by the contingency measures which undertaken after a spill has entered the environment.

The Contingency Plan by Sutherland (1979) pertains to a spill that has entered the aquatic environment. It identifies critical areas which should be protected by booms and other measures. Access points for people and equipment are also identified. The present Contingency Plan recognizes the seasonal importance of different habitats, establishing defense priorities accordingly. Individual energy facilities will be required to have their own spill prevention, containment, and cleanup plan. A critical element of any facility plan is that of informing the Coast Guard of all incidents, so additional resources can be brought into action rapidly if the facility's equipment is not able to contain and recover the spill.

Contingency plans require preplacement of essential supplies (booms, skimmers, absorbent materials) at strategic locations where they can be rapidly deployed. Essential elements towards effectively implementing a contingency plan include good command, communication, and training of the Spill Response Team. This requires that actual drills be performed periodically.

7.3.2 Dredging

Dredging will continue along the Columbia River and will occur at an accelerated pace to provide unobstructed shipping channels and berthing facilities for energy related commerce predicted for the next 25 years. The judicious location of channels, turning basins, and berthing facilities to reduce the initial volume of material to be dredged and the subsequent maintenance dredging is the foremost management consideration.

Clearly, a careful review of dredging permits by environmental agencies and a rigorous environmental impact methodology for determining impacts such as that prepared for the Dredged Material Research Program (Battelle 1974) and by OSU (1977) researchers, are secondary, broad management techniques of minimizing impacts. Aspects of operation or changes in flow pattern, turbidity, and salinity with their concomitant impacts on fish, wildlife, and their habitat may require permits to reduce or even prohibit dredging in specific locations. Careful monitoring during operations is necessary to ensure compliance with applicable measures.

Mitigating measures to reduce turbidity and any resuspension or redistribution of pollutants contained in the bottom sediments may include: 1) limiting hopper dredging, particularly in areas with fine silt and high organic components; 2) careful dewatering of dredged material prior to transportation by dredge or barge; 3) confining turbidity by suspending curtains around the dredge site; 4) prohibiting disposal of dredged material within areas of tidal or current influences; and 5) designing and regulating disposed areas to retain all deposited sediments.

Measures used to minimize entrainment rates of larger benthic invertebrates may include using alternative dredge types or modifying existing equipment. Stevens (1981), for example, suggests using clamshell dredges in areas heavily populated by Dungeness crabs and, where this is not possible, removing splash plates or modifying dragheads on other dredges.

Habitat loss can be mitigated by restricting disposal to areas previously altered and of little wildlife value. Upland disposal is preferred to all forms of wetland disposal especially since salt and sedge marshes, mudflats, and beaches are invaluable to shorebirds and waders. The disposal on uplands should provide a buffer strip adjacent to streams and sloughs.

Preferably, suitable dredged material should be stockpiled as potential fill for habitat enhancement (Soots and Landin 1978) or for future urban and industrial uses. This aspect of mitigation, however, should include interagency cooperation to determine optimum use.

Many other aspects of mitigation have been investigated by the U.S. Army Corps of Engineer's Waterways Experiment Station. Publications particularly significant include those covering water quality (Fulk et al. 1975; Bloom et al. 1976), plant reestablishment and succession on dredged material (Kadlec and Wentz 1974; Wentz et al. 1974; Parnell et al. 1978), and wildlife mitigation (Ocean Data Systems, Inc. 1978; Soots and Landin 1978). Specific management and mitigation recommendations for revegetating dredge materials in the Columbia River may be found in publications by Crawford and Edwards (1978), whereas recommendations for protecting sea and wading birds are presented in Peters et al. (1978).

7.3.3 Thermal Effluent and Related Cooling System Impact Mitigation

Any major facility may have local, microclimatic thermal effects. Operation in or near rivers or streams may raise water temperature through impoundment, alteration of flow, or removal of shading streamside vegetation. Section 7.4.1 discusses mitigation of these thermal effects for hydroelectric development, and Sections 7.1 and 7.2 discuss siting and construction mitigation for projects affecting water temperature through removal of riparian vegetation. A further important source of thermal pollution discussed in this section is the production of waste heat at energy conversion facilities. Thermal power plants, coal gasification plants and refineries are particularly important sources projected for the Columbia River Estuary, as the exothermic processes at these facilities require cooling water.

Cooling processes have in common the requirement of a heat sink, which may absorb excess heat from a working fluid. Heat sinks must be able to remove heat at a rate compatible with process requirements. With the exception of geothermal plants (at which the hot working fluid may be reinjected into deep wells), energy facilities have traditionally used the atmosphere or nearby waters as a sink for cooling. The higher specific heat and ease of manipulation of water made the utilization of aquatic systems an early preference of energy system engineers. Once-through cooling, a practice of removing water from an aquatic system, passing it through a heat exchanger at the plant's condenser where waste heat is absorbed, and returning the heated effluent to rivers, lakes, or coastal waters without treatment, has been the cooling method of choice of the electric industry. However, stringent water temperature standards have been adopted by Oregon and Washington to protect aquatic life, limiting application of this technology. The effects of thermal conditions on aquatic organisms in the Columbia River has been reviewed by the USEPA (1971), and EPRI (1978) has published a user's guide to a cooling system effects data base. The National Research Council (1980) has published a detailed review of the effects of once-through cooling and wet cooling towers.

The Electric Power Research Institute (EPRI) has also published a number of studies related to evaluation of cooling system environmental effects and various mitigation measures, including a methodology for evaluating cooling system effects (EPRI 1979a,b; 1980a), a methodology for assessing population and ecosystem effects of intake of cooling waters (EPRI 1980a), a bibliography of atmospheric and terrestrial effects of closed cycle cooling systems (EPRI 1980b), and an evaluation of a cooling lake fishery (EPRI 1979a,b; 1980a).

Cooling ponds or lakes transfer heat to the atmosphere through passive evaporation from the water surface. Spray ponds assist evaporation by increasing the area of water-air interface and by breaking down heated water into drops in a spray. All evaporative cooling systems, even though they are closed-cycle, require a source of make-up water to replace that consumed in the heat transfer.

Closed cycle cooling systems represent the state-of-the-art in thermal effluent mitigation. Though expensive, dry cooling towers are available, but have a high energy consumption and are useful primarily in arid lands, in which waste limitations compel strict conservation. Wet cooling towers are the technology most likely to be employed in the Columbia River Estuary. Information on cooling towers have been reviewed by Power Magazine (1967), Woodson (1969), and Parker (1974). Wet cooling towers release heat to the atmosphere by allowing heated cooling water to cascade downward through a rising column of air. Both evaporative and conductive heat transfer occurs. Air column movement may be natural (induced by tower design) or mechanical (propelled by fans). Natural draft cooling towers are the least expensive and most likely to be constructed in the Columbia River Estuary. These towers are shaped hyperbolically to induce draft and are hundreds of feet high, much higher than mechanical draft towers.

In all evaporative cooling devices, water is converted to a vapor and issues as a plume from the top of the tower. Plumes may produce local fogging and icing, increased cloud formation, higher relative humidity, increased precipitation, and even snowfall. Tower design, height, shape, and location all influence these local microclimate effects. Meteorological site research must be undertaken to properly locate towers to minimize local effects.

The wet cooling tower mitigates aquatic thermal effects, but consumes more water through evaporation than the once-through cooling system. Cooling reservoirs consume even more water by evaporation than do wet cooling towers. Water consumption in the lower Columbia is not likely to be a limiting factor (National Research Council 1980), but two alternatives are available to avoid both impacts. Dry cooling towers, described above, sharply reduce consumptive water loss. Alternatively, waste heat may be distributed to domestic and industrial users, for space and water heating and industrial process heat (Robertson 1979; National Research Council 1980).

In mitigation for cooling towers, two additional sources of waste are important. Cooling tower blowdown is a concentrated stream of corrosion products and chemical additives which are routinely purged to maintain the system. This wastewater discharge must be analyzed and treated using standard water quality techniques, or may be used for other inplant processes (i.e., ash transport) (Woodson 1969). Cooling tower drift contains the same impurities, carried from the top of the tower with the plume. Drift impacts are minimized by baffles (called drift eliminators), and by regular blowdown, and distribution of drift is influenced by the same design parameters discussed above relative to meteorological effects. Saltwater may be used in specially constructed cooling towers, but requires a high performance drift eliminator (Woodson 1969). EPRI (1979) has reviewed the chemical effects of power plant cooling waters.

Cooling water intakes have the potential to cause mortality to aquatic organisms through impingement and entrainment. Intake water flow volume is much greater for once-through cooling systems. High-capacity sand filters, reviewed by Nelson et al. (1978), have the ability to exclude most organisms and produce a low approach velocity at the intake, thus reducing impingement and entrainment.

7.4 FACILITY OPERATION

7.4.1 Hydroelectric Dams

Specific mitigation and management measures to protect or enhance fish and wildlife resources will vary with the location and type of hydroelectric projects. There is a low to medium probability of development of small to medium hydro facilities sited primarily along the tributaries of the lower Columbia River. Future hydro developments will be designed for either run-of-river or impoundment type operations with outputs ranging from 1 to 35 MW. A review of relevant concerns and mitigation measures was published by Fish and Wildlife Committee (1979), CRFC (1980), Tabor et al. (1980), CEC (1981) and USFWS et al. (1981).

Foremost among numerous concerns posed by future hydro facilities is the potential loss of the last viable natural-run spawning salmonids in the Columbia River. Hydro projects can act as physical barriers to migrating adult and juvenile fish and can inundate spawning habitat. Furthermore, operation of these facilities may have detrimental effects on a variety of aquatic organisms by altering natural flow regimes, benthic and riverine topographic features, and water temperature and water quality parameters such as dissolved gasses, sediments, and nutrients (USEPA 1971; Alley et al. 1977; CRFC 1980). General mitigation measures encompassing up- and downstream fish passage facilities, proper methods and timing of construction, hatchery propagation, construction of artificial spawning channels, and rehabilitation of spawning habitat are discussed in Sections 7.2.1, 7.2.2, and 8.2.1. A comprehensive water flow management scheme to maintain and improve specific fisheries, wildlife, and their habitats must be developed using site-specific criteria and be included as part of any mitigation package for future hydro projects (Fish and Wildlife Committee 1979; CRFC 1980).

The Columbia Basin Wildlife Technical Committee (USFWS et al. 1981), consisting of federal and state wildlife agencies, prioritized mitigation actions to offset impacts occurring with development of hydroelectic facilities. Their highest priority is the protection of existing habitat by avoiding critical and essential areas. Other measures include: "1) replacement of riparian vegetation out of reach of reservoir fluctuations; 2) creation of stable subimpoundments where habitat can recover; 3) stabilization of water fluctuations through specific reaches to permit reestablishment of habitat, and 4) dedication of specific reaches or reservoirs to wildlife management." Mitigation for facilities associated with hydro developments, for example, pipelines, roads, and electric transmission lines, are discussed in Sections 7.4.7, 7.4.8, and 7.4.9, respectively.

Construction of subimpoundments, ponds, nesting islands, and artifical nest structures are briefly discussed in Section 8.2.4. Completion of these improvements should precede filling of reservoirs (USFWS et al. 1981). When possible these structures should be constructed using recycled materials from associated excavation and building activities. Filling reservoirs slowly will decrease the rate of habitat loss and benefit fish populations (USFWS 1978). Leaving some vegetation within the inundation basin will create snags that are used by a variety of avifauna and increase the value of habitat for reservoir fish. Stabilizing impoundment shorelines and other riparian areas should use a combination of structural (e.g. rip-rap) and nonstructural means (vegetation). Structural techniques which preclude safe access or discourage use by wildlife should be discarded for alternate methods. Stabilizing riparian areas with rapidly growing native grasses (Bates et al. 1978), flood resistant trees (USFWS 1978), and species supplying food to wildlife (Section 7.1.1) is one of many acceptable methods to help attain this goal.

As previously mentioned, a comprehensive water flow management program is essential for mitigating future hydro projects. Among the many considerations for design of a successful program is the regulation of waters to avoid flooding of nest and den sites, to hinder access to islands by predators during critical use periods, and to avoid detrimental flows during migratory and spawning cycles of anadromous fish. Many of these periods have been identified by PNRC (1975) and Tabor et al.(1980).

7.4.2 Nuclear Power Plants

A nuclear power plant produces thermal and radiological emissions, wastewater from cooling tower blowdown, cooling tower salt drift, and highly radioactive waste. Mitigation for thermal and cooling systems related effluents is discussed in Section 7.3.4. The degrees of risk and adequacy of protective devices associated both with radioactivity emitted in routine operation and with radioactive waste disposal are highly complex and controversial issues. A detailed review of these issues is beyond the scope of this report. A recent review with references to the literature has been published as part of the Energy Future Report of the Harvard Business School (Bupp 1979). Other comprehensive reviews have been undertaken by the University of Oklahoma (1975), Seattle City Light (1976), Northwest Energy Policy Project (1977), the Evergreen State College (1978), Fenn (1980), and the National Research Council (1980).

This report projects a low probability for construction of a second nuclear power plant in the study area by 2006, possibly at the existing Trojan Nuclear Plant site. The primary means of mitigation for both routine and accidental radioactive emissions is through safeguards incorporated into the plant design itself. The nuclear industry is stringently regulated, and regulatory specifics and policy remain in a state of evolution. The Nuclear Regulatory Commission is responsible for the promulgation, inspection, and enforcement of design standards, which guard against radioactive exposure. The Nuclear Regulatory Commission or the above-cited references should be consulted if specific engineering design data is required by the Fish and Wildlife Service relative to specific environmental questions. The National Research Council (1980) has concluded that "the severity of ecological impacts expected from nuclear power cannot be reliably predicted at present, and may not be...until uncertainties surrounding reactor accident probability are resolved. In general, human health impacts should be far more significant than ecological impacts. Large populations of wildlife species will almost certainly survive genetic alteration from routine or accidental releases because of natural selection." Given the uncertainties regarding risk and the evolutionary status of the technology, it is not practical to present in this report a more detailed anaysis of mitigation measures for nuclear reactor operation.

Control practices relative to disposal of high level radioactive waste are, if possible, even more uncertain and are at an earlier evolutionary stage than those related to reactor operation. In general, both land and sea disposal has been considered. The National Research Council (1980) reports that land sites are preferred, since monitoring is easier, the environment is less corrosive, and food chain magnification would be less severe. On land, disposal of neutral wastes in salt deposits, and acidic wastes in glass or ceramic capsules, has been investigated. It is not possible at this point to predict which technologies will prove to be the most effective or economical. In the interim, spent fuel and liquid waste from any new reactor would almost certainly be stored either onsite or at Hanford, in water cooled tanks. The bulk of radioactive heat would be discharged in this storage. Leaks of radioactive materials during interim storage have occurred in the past, and special tank construction and monitoring is required (ERDA 1976).

An important management tool which should be employed, given these uncertainties, is an environmental radiological surveilliance program, such as the one conducted for PGE at the Trojan site. The Trojan program samples 85 locations, of which six are aquatic, and includes weekly air particulate and radiodine sampling, quarterly ambient radiation measurements using thermoluminescent dosimeters, monthly rainwater samples, semiannual terrestrial soil samples, semiannual terrestrial vegetation samples (including grasses, tuberous, and foliar fruits and vegetables), semiannual terrestrial animal samples of edible flesh and thyroid tissue (domestic livestock and small wild animals), monthly milk samples (cow or goat), quarterly well water samples, monthly surface and drinking water samples, semiannual bottom sediment dredge samples, and semiannual fish samples (PGE 1981). PGE (1981) publishes annual reports of its ecological and radiological monitoring programs methods and results.

7.4.3 Coal Gasificatiom Plant

A high probability of development of an additional gas fired thermal power plant at the present Beaver plant site is projected within 1987 to 1996. No other fossil-fuel power plants are projected. A medium probability is assigned to the possibility that gas will be supplied by onsite gasification at Beaver. Gas combustion is typically clean, requiring less environmental controls than oil or coal combustion. The net effect of gasification is to shift the requirements for control of emissions and effluents from the power generation to the fuel preparation phase (USEPA 1976a). Therefore, the primary mitigation concern associated with thermal power generation in the Columbia River Estuary is likely to be associated with preparatory coal gasification.

Table 7-1, prepared in 1973 by USEPA and referenced in Rickles and Whitenight (1980), lists the waste streams, principal components, source, disposition, and mitigation process for all pollutants from a coal gasification facility. The fact that low-sulfur, low-ash Western coal would be used in a Columbia River Estuary plant is of considerable mitigatory value. Coal gasification processes are designed to be closed chemical systems. The commercially proven Lurgi process, on which this review focuses, is designed for zero effluents. Almost all organic by-products are removed in various process stages. The soluble phenol fraction is removed in the Phenolsolvan process. Inorganic by-products (NH_3, H_2S, HCN) are treated by stripping and oxidation in conventional sour water treatment. Table 7-2 shows wastewater characteristics before and after treatment for a 250 million cubic feet per day production plant using the Lurgi gasification process. Treatment includes three-stage oil-water separation, filtration, phenol recovery, ammonia still, and activated carbon treatment (Hittman Associates, Inc. 1975a).

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Table 7-1. Source and characteristics of major wastes in streams affected by the gasification of coal.

Waste	Principal chemical components	Sources	Disposition	Process
Coal dust	Carbon particles	Feedstock crushings grinding	Containment and recovery	Cyclone separators, bag filters, enclosure
Stack gas	CO_2, SO_2, N_2, O_2	Stream generation Stack gas generation	Treatment/discharge	Wellman-Lord, limestone injection, line scrubbing, catalytic oxidation, double alkali, Citrate
	Nitrogen	Oxygen generation	Discharge	
Acid gas	H_2, CO_2, CH_2, COS, H_2S, N_2	Product of shift conversion	Sulfur recovery	H_2S can be selectively removed from a gas stream by a rectisol hot potassium carbonate, Sulfinol, MEA, DIPA, or similar process. Claus and Stretford processes recover elemental sulfur from H_2S rich streams. Tail gases from these units can be treated by incineration, Beavon, Wellman-Lord, or SCOT process.
Exhaust emissions	CO, HC, NO_x, particulate	Automobile traffic	Discharge	
Runoff leachings	Pyrites, sediment, oil Organic matter	Feedstock storage Ash ponds	Treatment/utilization	Neutralization
	Sediment	Land surface	Discharge	Settling
Wastewater	Dissolved salts NH_3, phenols, cyanide Thiocyanate, BTX	Water treatment Gasification Product of shift conversion Methanation	Treatment/utilization Treatment and reuse	Coagulation Chevron, Phenosolvan, Phosam, biological oxidation

(continued)

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Table 7-1. Concluded.

Waste	Principal chemical components	Sources	Disposition	Process
Blowdown	Dissolved salts	Boilers/cooling towers	Treatment and reuse	Chevron, Phenosolvan, Phosam, biological oxidation
Cooling water	Heat	Heat exchangers	Utilization, discharge	Waste heat recovery, cooling towers
Sanitary sewage	Organic/nitrogen compounds	Washrooms	Treatment and utilization	Biological oxidation
Rocks and debris		Feedstock cleaning	Disposal, utilization	Landfill/construction material
Tar	COD, DS, SS, CO, CH_4, Phenols, NH_3, HCN, Thiocyanate, H_2S	Gasification	Utilization	Conversion to oil, direct gasification
Char	Fixed carbon, sulfur	Gasification	Disposal/utilization	Gasification, desulfurization, direct combustion
Ash	Inert residue	Gasification, steam generation	Disposal/utilization	Landfill/incorporation in construction materials
Spent catalysts	Cobalt, molybdenum, iron	Shift conversion	Treatment and recovery	
	Bauxite	Sulfur recovery	Treatment and disposal	Oxidation
	Nickel	Methanation	Treatment and disposal	
Spent purifying media	Iron or zinc oxide	Final purification	Treatment and disposal	Oxidation
Sludge	Spent carbon	Final purification	Disposal	
	Sulfites	Stack gas cleanup	Treatment and disposal	
Refuse	Solids, biomass	Wastewater treatment	Treatment and disposal	Dewatering, oxidation, landfilling
		Work areas	Treatment and disposal	Incineration, landfilling

Source: Rickles and Whitenight, 1980.

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Table 7-2. Wastewater characteristics for a plant synthesizing 250 million cubic feet per day of natural gas using the Lurgi gasification process.

Waste	Before treatment	After treatment
Thiocyanate	0	0
Cyanide	0	0
Ammonia	15,900	16
Sulfide	1,400	1
TSS	600	34
Organics		
Phenols	9,960	<1
Oil	1,100	15
COD	0	0

Source: Hittman Associates, Inc. 1975b; referenced in Rickles and Whitenight, 1980.

The Koppers-Totzek process, also commercially proven, does not produce by-product tars, oil, phenols, or naptha due to its higher operating temperature. Typically, tars, oils, phenols, ammonia, and sulfur are recovered within the plant. Lime sludge from sulfur recovery, blowdown water from the cooling system, wet ash from the boiler, and flue gas are the primary paths of environmental impact. In-process wastewater controls are based on the recycling of process water for cooling and scrubbing. End-process pollution controls may include primary treatment (clarification), secondary treatment (biological degradation) and tertiary treatment (dissolved and suspended solids). In recycling wastewater, treatment focuses on meeting process quality criteria. From the sour water stripper and other control systems, process water moves through the biological treatment to the cooling tower. Phenols are, for example, first reduced to 500 ppm by the Phenolsolvan process and then to 3 ppm in the stream moving to the cooling tower (Rickles and Whitenight 1980). Ammonia is condensed and stored for sale as an aqueous solution, with 5 ppm moving to the cooling tower (Rickles and Whitenight 1980). Both CO_2 and H_2S are collected from the deacidifier column and sent through the Rectisol process to the sulfur recovery process (Rickles and Whitenight 1980). BOD_5 is reduced from 2500 ppm to 75 ppm, but TSS increase from a negligible amount to about 5 ppm arriving at the cooling tower. However, carcinogenic organics may remain in the cooling tower drift despite these treatment steps (Rickles and Whitenight 1980).

The high solid waste volume from the coal gasification process may constrain location in the Columbia River Estuary. Typically, these wastes are disposed of in the mine. Solid wastes are primarily coal ash collected from various points in the process, but also include some sludge from water treatment, sulfur recovery, and biological treatments. Toxic materials are present and may leach from the landfill site. Leachate must be diverted and treated by neutralization, precipitation of metals, settling, and oxidization. The ash pile may be solidified by the addition of a small amount of water. Evaporation ponds which contain coal pile runoff must be sealed. Solid waste includes a small concentration of radioactive isotopes; little control is practiced for these. (Doses from an agglomeration ash process are about 7.6 x 10^{-4} curie of Ra-226, Th-228 and Th-230 per 10^{12} Btu input.) Hydrogen flouride may be controlled by the addition of calcium oxide in the gasifier, which will react with HF and cause it to be carried out with the ash. Chemicals used to regenerate demineralizers (Ni, Co, Fe) also end up in the ash waste; they may form highly toxic carbonyl compounds and leach from sludge.

Ammonia, sulfur dioxide, hydrogen sulfide, and hydrogen cyanide are principal potential air pollutants of the coal gasification process. Ammonia recovery is described above. Hydrogen sulfide is the primary sulfur component of the waste gas stream. The sulfur recovery system converts H_2S to the less harmful SO_2, and removes as much sulfur as possible. The Claus system is 95% efficient (Rickles and Whitenight 1980). Burning Claus tail gas converts H_2S to SO_2, which may then be scrubbed with conventional FGD equipment. The Stretford process is a wet method for removal of this and other gases. Claus tail gas may also be further treated in the Beavon, Cleanair, or IFP processes, which are 99.5% to 99.9% efficient (Rickles and Whitenight 1980). Sulfur may also be captured with dolomite in fluidized bed combustion. SO_2 is the principal air emission from the sulfur recovery system and the coal gasification plant. HCN, formed by a secondary reaction between carbon and ammonia in the gasifier, may be suppressed by increasing the partial pressure of steam, or may be removed with H_2S in the Stretford (or other) sulfur recovery system.

Rickles and Whitenight (1980) cite the following trends in coal gasification pollution control: (1) utilization of processes with reduced and more controllable emissions; (2) improved product gas purification; (3) upgraded sulfur recovery and tail gas cleaning; (4) treatment of cyclic hydrocarbons in wastewater; and (5) removal of acidic components from wastewater.

7.4.4 Refineries

There is a low probability that a new refinery will be built in the study area by 2006. Nevertheless, refineries primarily influence the environment through the release of atmospheric pollutants and liquid effluents. Particulates and noxious gases are released in cooling tower emissions and stack effluents. A significant amount of process water which has been in contact with chemicals must be treated.

Particulates, hydrocarbon, sulfur oxides, nitrogen oxides, ammonia, hydrogen cyanide, and other emissions from stacks must be reduced through the best available technology as prescribed by the Clean Air Act of 1970 and Amendments to Clean Air Act, 7 August 1977. Feed streams and tail gas emissions are primarily reduced by the Claus process and other aspects of catalytic cracking (Phillips 1980). Fugitive emissions from valves can be significantly reduced through routine screening and maintenance procedures (Wetherold and Preston 1980). Electrostatic precipitation and scrubbers, and the use of other pollution abatement devices have been developed to meet federal and state standards for emissions of harmful pollutants.

Effluents in refinery waste water systems can be reduced by the following treatment steps: 1) primary separation to remove oil by gravity; 2) intermediate separation to remove suspended solids and additional oil by chemical sedimentation or air floatation; 3) secondary treatment to reduce the BOD with some type of biochemical oxidation; 4) tertiary treatment to remove dissolved organics which will not degrade with biological treatment methods. Carbon absorption is the most common means of tertiary treatment (Phillips 1980). Compliance with the Federal Water Pollution Control Act of 1972 and the NPDES management practices (USEPA 1979) will insure minimal detrimental impacts to fish, wildlife, and their environment.

An ongoing sampling program to detect airborne emissions and waterborne toxics in soil, water, fish, and vegetation (particularly aspects of acid precipitation on aquatic and terrestrial systems) would be a significant measure in early detection and mitigation of adverse impacts.

Detailed management and mitigation measures for adverse refinery operations or procedures may be found in Elkin and Constable (1972), Bryant (1973), Azad (1976), Hustvedt and Quaney (1977), Laengrich and Cameron (1978), and Rosebrook (1980).

Existing regulations stipulate the control and disposal practices for toxic substances and other hazardous wastes; these must be in accordance with approved plans for treatement and containment. Contingency plans to mitigate the adverse effects of hazardous material spills are currently required as part of management and mitigation at refineries.

7.4.5 LNG/LPG Facilities

LNG/LPG facilities would require marine vessels for delivery, marine terminals, and the facility itself, which may transfer LPG, or gasify LNG before putting it into a pipeline distribution system. Marine vessels carry a risk of oil spill, which was discussed in Section 7.3.1. There is also a risk of fire and explosion, especially with LNG. This hazard is greater for the vessel than for the facility. There is only a low probability of an LNG facility being developed by 2006 in the study area.

Principal mitigation measures of LNG/LPG are remote siting, complete, routine inspection and maintenance of LNG/LPG facilities and vessels, and specific precautions associated with vessel transits, such as tugboat escorts, restriction of other traffic, and crossing the Columbia River bar when environmental conditions are not severe. Because the LNG/LPG vessels navigate through the estuary and river, other areas are exposed to a potential for fire and/or explosion. This risk is severe enough that if LNG vessels transit within 3 miles of the Trojan nuclear plant or if an LNG facility is located nearby (such as on Cottonwood Island), the risks to the Trojan Plant would probably have to be evaluated for the Nuclear Regulatory Commission (OIW 1978b).

The Oceanographic Institute of Washington (1978b) has thoroughly researched the subject of LNG and LPG hazards management in Washington State and has prepared a detailed bibliography on the subject (OIW 1979).

7.4.6 Marine Terminals

The construction of new marine terminals along the Columbia River within the next few years is inevitable. Energy facilities are specifically sited adjacent to the Columbia River because of easy access and the use of ships, barges, and other cheap transportation modes. Additionally, raw products and the distribution of finished goods to and from international markets are transshipped through marine terminals.

Management and mitigation during the construction and operation of a marine terminal must encompass both the terrestrial and aquatic habitats. Management actions generally include extensive preconstruction public and agency consultation during which primary concerns of destabilization, loss of benthic production, fisheries deterioration, water quality degradation, and loss of wildlife habitat (especially wetlands) are discussed. The scoping process, designed to identify the pertinent issues is invoked as part of an interagency management evaluation.

Numerous mitigative activities are usually incorporated into the facility plans to reduce adverse impacts and to anticipate permit conditions and other regulatory requirements. These include: 1) careful siting to locations offshore, upstream, downstream, etc. to minimize dredging, especially near river deltas, wetlands, and important wildlife habitats; 2) minimizing the discharge of surface runoff through containment, removal, or treatment; 3) controlling the infiltration to the water table of contaminants resulting from terminal construction and operation; 4) revegetating the construction site to reduce erosion and sedimentation; 5) reducing the risk of explosion or hazardous emissions through carefully established and supervised fuel handling procedures; 6) facilitating road and rail access and scheduling deliveries to minimize adverse effects; 7) complying with all navigational requirements including Coast Guard lighting regulations, accident contingency plans, etc.

Dredging for the berthing facility results in the most significant impact to water quality and aquatic animals. Dredging and related water oriented activities mainly fall under the jurisdiction of the U.S. Army Corps of Engineers. Extensive management and mitigation procedures have been published by the U.S. Army Corps of Engineers and have been reviewed in Section 7.3.2 Dredging.

More specific marine terminal management and mitigation procedures must relate to the function of the terminal and particularly to the fuel and other products transferred. For example, management at coal terminals is primarily directed to mitigating particulate emissions which are extensively covered in the Technical Guidance for Control of Industrial Process Fugitive Particulate Emmissions (USEPA 1977).

Further management and mitigation measures for impacts at marine terminals that combine facility operation with shipping, such as LNG/LPG transfer and OCS development, are described in the treatment of specific facility sections.

7.4.6.1 Coal Terminal. A coal terminal requires facilities for receiving, unloading, stockpiling, reclaiming, and perhaps reloading and transshipping coal. Coal terminals are projected with high probability at Kalama and Tongue Point and with low to medium probability at several other sites. Coal handling and storage at a coal gasification plant (Section 7.4.3) (or any other large facility using coal) have much in common with handling and storage at a terminal, and all related management and mitigation is combined for discussion in this section.

Coal may arrive at the terminal or plant in unit trains, barges, trucks, or slurry pipeline. Among these options, transportation by unit train from coal fields in Montana, Wyoming, or Utah to a lower Columbia River terminal is by far the most probable scenario in the Northwest. The USEPA (1978) has reviewed the impacts and mitigation for all these transportation modes. Valuable discussions of coal transportation, pretreatment, processing, storage, and handling are also contained in Hittman Associates (1974, 1975), University of Oklahoma (1975), Dvorak and Lewis (1978), ORNL (1978a), and OTA (1979).

Barge transportation of coal will probably be limited to the upper river, above Portland and out of the study area. Barge loading and unloading by clamshell bucket produces a significant particulate emission, but there is little available dust control measures for off-loading barges (USEPA 1978). The problem may be circumvented by the use of containerized barges (see Section 2.4.3.1.2). Alternatively, the receiving bin may be equipped with sprayers for dust control, and the sides may be extended to provide wind protection when discharging (USEPA 1978). Negative pressure may be maintained to provide a downward flow of air into the bin to contain dust. Covered barges may be used to control fugitive dust.

Coal arriving in unit trains of 100 cars or more, each with a capacity of 100 tons, at a rate of three to five or more trains per day, may present serious air pollution and noise-related effects. Controlling these at their source will alleviate most indirect impacts on fish and wildlife. Coal unloading operations at the terminal may use enclosed rotary car dumpers for emptying unit trains with minimum fugitive dust (Power Magazine 1967). In the Northwest, watering coal may be effective in reducing wind loss in transit and dust in unloading (USEPA 1978). Western subbituminous coal has a high moisture content and generates less dust than other coal sources (USEPA 1978).

In transit, windguards of 30 cm height are partially effective (USEPA 1978). Coal loads may be sealed with a latex polymer or an asphalt emulsion; also, dustproofing coal with oil or calcium chlorides is common (USEPA 1978). Removable tarpaulins are expensive and wear out quickly; Bechtel has developed a flip top lid for gondola cars which is in use on the Milwaukee Railroad (USEPA 1978). Noise may be reduced by use of electric rather than diesel locomotives. Use of diesel exhaust mufflers, incorporation of acoustical absorbent material in the engine casing, and use of continuous welded rails may all reduce noise impacts on the way to the terminal.

At the terminal or gasification plant, a storage yard will be required to hold coal for transshipment or as an active or emergency supply. Dust may escape from the pile during loadout and reclamation, or may be stirred by vehicle movements or wind; this may be controlled by watering. Proper compaction and contouring will decrease dust and vapors and reduce the hazard of spontaneous combustion (Power Magazine 1967; Dvorak et al. 1978). Mulching, revegetation, riprap, and chemical additives are also used (Dvorak and Lewis 1978). However, constant use of the pile prevents stability and limits treatment options. Silo storage and loadout may reduce fugitive dust to negligible levels; earth berms may also be placed around the pile (USEPA 1978).

If not contained, water runoff from the pile may contaminate the estuary or other local waters. The pile itself must be well drained; however, runoff must be contained and treated onsite. Runoff and drainage patterns can be manipulated by reducing slopes, setting ditches, etc.

It is likely that any cleaning of coal will be done before long-distance transport, to reduce weight. Therefore, it is improbable that major cleaning impacts will require mitigation in the Columbia River Estuary. Cleaning itself mitigates impacts of coal use by removing mineral matter, trace elements, sulfur, and ash. If coal is cleaned, cleaning wastes may be disposed of on land. Toxic, acidic, and fire hazardous wastes must be covered with overburden and all wastes should be compacted, contoured, and revegetated to reduce erosion and runoff. Ground liners (see Dvorak and Lewis 1978) may be necessary to protect groundwater against infiltration.

A final coal handling activity requiring mitigation at a coal transshipment terminal is the reloading of coal onto ocean going ships for export. The Port of Kalama and Pacific Resource, Inc., joint proposers of the Kalama terminal, envision use of a 72-inch conveyor belt to reclaim coal from the pile and transfer it to the ship's hold. Covered belts and enclosed, hooded transfer points provide the maximum emission control.

The USEPA (1978) rated priorities for research and development of environmental controls for coal handling, placing the issue of controlling toxic water effluents from coal storage and cleaning waste piles at a high priority and the issue of fugitive dust control at a medium priority.

7.4.7 Pipelines

Pipelines will be constructed and operated in conjunction with many of the energy developments projected for the Columbia River Estuary. General mitigation actions for the construction phase of pipelines are discussed in Section 7.2. Operation of pipeline facilities should be in accordance with requirements of the Code of Federal Regulations (Title 49, Parts 192 and 195). Basic mitigation categories for the operation of pipelines include: 1) habitat restoration; 2) monitoring and maintenance of pipelines and associated facilities; 3) maintenance of pipeline corridors, and 4) minimizing the potential damage resulting from accidental pipeline leaks and failures.

Minimizing habitat disturbance and restoration of degraded habitat are discussed in Sections 7.2 and 7.4.8. Rapid restoration efforts coupled with monitoring of mitigation actions should be emphasized, especially in or near aquatic and riparian habitats.

Pipeline monitoring and maintenance should include continual surveillance, periodic quality control checks, and hydrostatic testing. Weekly aerial surveys and monthly ground surveillance will provide early detection of potential problems which should be followed by preventive maintenance. Properly engineered and constructed submarine pipelines should be inspected by divers or submarines, when possible, for erosion or displacement. Inspection of substations, pipes, and valves should be conducted to detect damage from vandalism, detect leaks, evaluate conditions of valves, pipes and corrosion preventive coatings, and check the condition of the surrounding environment. An overview of periodic quality control checks and equipment to conduct inspections for gas pipelines is presented by Northwest Pipeline Corporation (1980). Fulton (1979) has summarized the corrosion control program of the U.S. Office of Pipeline Safety Operations for gas pipelines.

Hydrostatic testing in accordance with specified procedures will test the integrity of pipeline welds. To remove scale and rust, the interior of an uncoated pipe will require washing prior to testing. Internal coatings on pipes will preclude this measure. Reducing the velocity of discharged water at pipe exits, using energy dissipating devices (e.g., T-pipe), will reduce soil disturbance and erosion. Discharge should be sampled and stopped if TSS or sediments are too high. Effluents should be directed to and stored in approved retaining pits.

Practices for maintaining pipeline corridors are similar to those employed for road, railroad, and power transmission line ROW's. The methods for managing vegetation and minimizing disruption and alteration of movement patterns and use of these habitats by fish and wildlife are addressed in Sections 7.4.8 and 7.4.9.

Quality control during construction and adequate monitoring and maintenance of pipelines will help reduce the chance that serious spillage may occur. Leak reporting requirements should be in accordance with 49 CFR, Part 91. Proper design and siting of pipelines and placement of containment structures will help to minimize the extent of the damage if spills occur. Properly constructed berms should be placed around pipelines and all onsite storage tanks. In conjunction with berms, drainage systems should be installed to direct and store spilled material for later removal and proper disposal at approved sites. Maintenance personnel should be educated in the proper spill abatement procedures and should be equipped with tools and equipment necessary for containment and clean-up of accidental spills. A Gas Dispatch system or similar early detection devices should be properly employed to immediately detect leaks and, thus, facilitate containment of materials (Petroleum Extension Service 1973; Northwest Pipeline Corporation 1980).

Reducing the hazards from dragging ship anchors can be attained by burying lines at least 3 m (10 ft) below the substrate and installing automatic block valves at each shore. The potential for accidents also can be minimized by prohibiting ships from anchoring in the areas of pipeline crossings, erecting markers on each shore, operating a sufficient mariner traffic control system, and issuing properly marked up-to-date charts (Oceanographic Commission of Washington 1975). Fishing trawlers using otter boards or other equipment which might damage pipelines should be prohibited at crossings. Adequate spacing between parallel pipelines can alleviate the hazard of a single accident simultaneously rupturing both lines.

Corrosion protection of submarine pipelines can be afforded by using coating materials (e.g. plastic, asphalt, or coal tar) protected by concrete, which also will weight the pipeline and avoid displacement. A cathodic protection system will further help prevent corrosion.

In addition to other prevention and protection measures, spill contingency plans and liability funds should be designed to assist in mitigating damage from possible spills and associated occurrences such as explosion and fire.

7.4.8 Railroad and Highway

Fundamental impacts to fish, wildlife, and their habitats resulting from the operation and maintenance of roads, highways, and railroads can be classified into six broad categories, to which mitigation should focus. These categories are as follows: 1) loss, degradation, and fragmentation of habitat; 2) direct mortality to wildlife; 3) disruption and alteration of movement patterns and the use of habitat by fish and wildlife; 4) alteration of drainage patterns and hydrologic regimes; and 5) increased introduction of air, water, and soil pollutants. To support any new energy facility, necessary access and maintenance corridors will have to be constructed, and the existing system of roads, highways, and railroads will probably be modernized and expanded. Publications addressing the environmental hazards and mitigation measures relevant to highways and railroads include Ward et al. (1976); Adams and Geis (1978); Erickson (1978); Shuldiner and Cope (1979); and Cramer and Hopkins (1981).

The construction of highways and railroads greatly alter the immediate habitat area, and the abundance, distribution and habits of birds and other animals are locally changed. Wildlife are frequently killed by collision with moving vehicles (Ward et al., 1973, 1976). Probably only in isolated cases do their losses significantly alter the population. Large ROW's can impede migration and have a severe effect on some mammal populations (Ward et al. 1976, Wallmo 1981). The edge effect of the ROW's may benefit certain birds and other animals.

Fencing of ROW's should be minimized. However, where fencing is required, for example to exclude domestic livestock or alleviate wildlife-vehicle collisions, it should be constructed to meet proper specifications. Barrier fences should be of sufficient height, mesh, basal closure, strength, and permanency (CDH 1973; Woodard and Reed 1974; Ward et al. 1976; Falk et al. 1978). One-way gates should be installed to allow wildlife to escape if trapped in the ROW (Reed et al. 1974). Specifications for fences that exclude livestock but allow passage of large ungulates are discussed by USDA (1969), Kerr (1979), and Yoakum et al. (1980). Overpasses or underpasses (designed on a site-speciific basis) should be constructed in conjunction with barrier fences (Reed 1969; Reed et al. 1973; Ward et al. 1976; Reed 1981a). Direct mortality resulting from wildlife-vehicle collisions can also be alleviated by employing a variety of lighting techniques (Gallagher and Meguire 1974; Reed 1981b), speed bumps, warning signs (Mansfield and Miller 1975), and lower speed limits. Ford (1980) evaluated various mitigation measures to offset deer mortality along a major highway in California.

Vegetation along ROW's should be managed to enhance its value to wildlife. Use of herbicides should be minimized and applied by experienced personnel under optimum atmospheric conditions. Mowing should also be minimized or allowed on a rotational basis, leaving alternate sides of the ROW untreated (Voorhees 1977). Mowing of vegetation just prior to or during nesting season is detrimental to the birds and should not be allowed.

Tertiary roads including power transmission line access and maintenance roads can be designed and modified to produce suitable wildlife habitat. For example, roadside vegetation can be maintained as hiding cover and travel lanes for large mammal crossings (Ward 1976; Willey and Marion 1980). ROW's can be managed for uneven-aged stand vegetation to maximize diversity and structure. Power transmission line roads should be routed to decrease line-of-sight distances using dead-end and spur roads (USFWS et al. 1981) and vegetation screens (WDG 1970 in USFWS et al. 1981), and to reduce straight stretches of road (Montana Cooperative Elk-Logging Study 1975). Planting appropriate food sources along ROW's can enhance its value for wildlife (USDA 1969; Taber 1977; Merker and Hale 1980). Maintaining and producing snags (Thomas et al. 1979), establishing brush piles, and arranging slash materials for fire protection will help protect and produce valuable habitat.

Upgrading of ROW's should include adequate drainage, storage, and cleansing systems to minimize the impact of polluted (toxic substances and sediment) runoff waters on the adjacent environment. Several such systems are discussed in Section 7.2.1.

Mitigation measures to deal with the impacts of coal and road dust are discussed in Sections 7.4.6.1 and 7.2.1, respectively.

7.4.9 Electric Transmission Line

The effects of electric power lines that require consideration for mitigation are bird/wire collision mortality, excessive habitat alteration at least for some species, ROW maintenance activities, stream alteration where applicable, and disturbances by outdoor recreation vehicles and hunters. Whether electric fields have an affect on wildlife is unlikely, but still debated. A medium probability for major transmission line upgrade on the Oregon side of the lower Columbia River is projected for 2006.

Mitigation recommendations for avian collisions are provided by Meyer (1978), the USFWS (1978b), and James and Haak (1979). Avoidance of areas which have high bird use, or are used by special status species with high flight intensities at the proposed line height is recommended in siting the corridor. Upgrading or expanding existing corridors or paralleling existing barriers may minimize new impacts. A long-term, indirect mitigation measure is to encourage energy policies emphasizing load-center generation, conservation, and renewable resources. If areas with high collision potential must be crossed, low configuration towers and the elimination or marking of overhead groundwires may reduce collision frequency. Other mitigation options include placing lines underground, diverting birds by modifying habitat and creating alternative habitat, increasing visibility, changing conductor configuration, creating shelter belts, and repelling birds with corona noise and predator and distress calls.

Habitat loss in wetlands and other areas of naturally low-growing vegetation is limited to tower footings and access roads. In forested areas the value of habitat diversity created by corridor edge and low vegetation may be of net benefit to wildlife, even considering increased hunter pressure along access roads (Goodwin 1975).

ROW maintenance activities may contribute to habitat diversity, but herbicide application requires mitigatory controls. Annotated bibliographies prepared by EPRI (1979) and ORNL (1978b) on transmission and ROW effects provide an introduction to the literature and various mitigation actions which have been used or are recommended. The USFWS report provides a detailed review of transmission line effects and mitigation. Section 7.3.8 further discusses transmission corridor mitigation related to access roads.

Raptors are vulnerable to electrocution on powerlines; however, mortalities almost always occur on distribution lines, as transmission lines are typically widely spaced, so that contact with a ground and live wire is nearly impossible. Olendorff et al. (1981) have extensively summarized the literature on raptor electrocutions and provide detailed design data on powerline modification for raptor protection. Siting and design options include undergrounding, insulation, armless construction, alternative pole, crossarm, conductor configurations, perch management, and siting away from raptor nests. Olendorff et al. (1981) have also summarized the means by which transmission lines can be used to benefit local raptor populations, particulary golden eagles and large hawks, through construction of artificial nest platforms.

7.4.10 Oil and Gas Wells

7.4.10.1 Onshore. Several oil and gas wells along the Columbia are now producing commercial quantities of oil and gas. Exploration rights have been sold for several other sites in the vicinity of Cathlamet and Puget Island. Renewed interest in exploration and drilling activities is likely to occur within the Columbia River Estuary during the next five years and beyond.

The Washington State Oil and Gas Conservation Committee is currently revising the 20-year old regulations governing oil and gas drilling, to reflect the requirements for safe and environmentally sound drilling. These plans will dictate management and mitigation measures prior to construction and during operation. Drilling for oil and gas in Oregon is anticipated to require construction and operation constraints of a similar nature.

Management and mitigation strategies for oil and gas exploration more likely will conform with existing environmental regulations protecting air, water, and biota. Specific management and mitigation measures that may be used at onshore oil and gas wells have been described in Poland and Davis (1971), Reid and Streebin (1972), Reid et al. (1974), USDI BLM (1976), and Wilkins (1977). These include:

Strictly enforcing laws prohibiting drilling through water

Using slant or directional drilling under sensitive areas to protect plant and animal communities and sensitive aquatic environments directly above fuel deposits

Avoiding and/or stopping drilling in aquifer zones to minimize contamination by drilling fluids, brine, hydrocarbons, etc.

Carefully reviewing all drilling activity, construction schedules, and pipeline designs to minimize adverse environmental effects

Avoiding environmentally sensitive areas such as critical wildlife habitats in siting pump stations and maintenance bases

Monitoring all ongoing activity

Reducing flammable, combustible, and toxic vapors produced at wellhead

Preparing an accident contingency plan to minimize contamination of marshes, riparian habitats, and other sensitive environments and to stop fuels from entering river and channel

Containing all byproduct waste water such as brines that are used in drilling

Landscaping pump station locations

Removing all wastes from site and using these for landfill or other purposes

Removing abandoned gas compressors, concrete pads, and any other materials and restoring the site to its original condition.

7.4.10.2 Outer Continental Shelf. OCS oil and gas exploration and development require a number of onshore support facilities and operations. Examples are fabrication yards, supply and pipe storage, oil pipeline landfalls, bulkheads, and dredging and transportation facilities and operations, all of which have some degree of environmental impact on estuaries depending upon the circumstances.

In effect, OCS oil and gas development's only direct impact is that of requiring additional port facilities. These facilities may require dredging or filling, which would result in a loss of wetlands that would necessitate mitigation. This impact is reduced if piers can be constructed out to deeper water and if sufficient upland area already exists. Hence, site selection is the first step in mitigation. It is most likely that any OCS support would be located near Astoria, the transit distance being unfavorable further upriver, and the dredge and road requirements being unfavorable on the Washington side of the estuary.

OCS oil and gas support at present would only serve exploration needs, since no offshore oil or gas fields with development potential have yet been discovered. Oregon/Washington OCS oil and gas development is not a high priority site for industry.

OCS oil and gas development may carry a major secondary impact of rapid growth of the local work force and population, with the possibility of subsequent decline.

A major impact of OCS oil and gas development could arise from the construction of a pipeline to shore. This impact is not significant to the estuary unless the landfall is nearby. In that case, there is a possibility of spilled oil from a pipeline failure entering the estuary at its mouth, especially under winter conditions of strong waves and onshore winds.

CHAPTER 8.0 FISH, WILDLIFE, AND HABITAT ORIENTED MANAGEMENT AND MITIGATION

8.1 INTRODUCTION

Fish, wildlife, and their habitats are afforded protection by specific environmental regulatory laws and ordinances. Some of the federally mandated acts and statutes are: the NEPA, the Environmental Quality Improvement Act of 1970, the Noise Control Act of 1972, the Clean Air Act, the Solid Waste Disposal Act, the Environmental Education Act, the Federal Water Pollution Control Act, the Water Resources Act of 1964, the Water Resources Planning Act, the Marine Protection Research and Sanctuaries Act of 1972, the Fish and Wildlife Coordination Act, the Coastal Zone Management Act of 1972, the Refuse Act of 1889 (the Rivers and Harbors Act of 1899), the Endangered Species Act, the National Wilderness Preservation System, Wild and Scenic Rivers, the Organic Act of 1897, the Multiple Use-Sustained Yield Act, the Forest and Rangeland Renewable Resources Planning Act of 1974, the Federal Environmental Pesticide Control Act of 1972, the Energy Supply and Environmental Coordination Act of 1974, and the Mining and Minerals Policy Act of 1970.

State agencies can also regulate activities concerning fish, wildlife, and their habitats by the issuance of licenses and permits. Table 8-1 lists some of the Washington State agencies and their permits that relate to fish and wildlife and their habitats. Oregon and Idaho probably have similar permitting requirements. Local agencies have little direct control of fish and wildlife, their primary influence being indirect through pollution control agencies, departments of public works, and other offices.

The purpose of many listed acts, laws, policies, and permits is to encourage harmony between man and his environment by promoting efforts to prevent or eliminate damage to fish, wildlife, and their habitats, all of which exhibit values difficult to identify and quantify. Additionally uniform control, mitigation, and management standards do not always exist. Populations and habitat must be considered in the context of ecologically complex concepts. Ecosystem dynamics, nutrient pathways and trophic interactions are not clearly understood. Fish and wildlife management encompassing sophisticated ecological interrelationships as found in the Columbia River Estuary requires a flexible strategy in which species and their habitat are coanalyzed within specific locations. Because of this complexity, uniform control, mitigation, and management standards do not always exist.

Mitigation as defined in NEPA by the President's Council on Environmental Quality (40 CFR Part 1508/20(a-e)) includes:"...a) avoiding the impact altogether by not taking a certain action or parts of any action; b) minimizing impacts by limiting the degree or magnitude of the action and

Table 8-1. Washington state agencies that issue permits for activities that relate to fish, wildlife, and their habitats.

State agencies	Types of permits
Aeronuatics Commission	Reporting location of hazardous structures or obstacles
Department of Agriculture	Livestock Auction Markets Feed Sales License Nursery License Permit to Process Certified Seed Seed Labelling License Pesticide Permit Fertilizer Sales Shipping Permits Warehouse Operation Garbage (feeding) Removal of Offal Permit Rendering Plant Operation Independent Collector
Department of Ecology	Weather Modification Permits New Source Construction Approval (notice of construction, registration of source) as to air pollution Burning Permit Burning of field and turf grasses grown for seed Flood Control Zone Permit Approval of Change of Water Right Dam Safety Approval Permit to Appropriate Public Waters Sewage and Industrial Waste Treatment Facilities Approval Waste Discharge Permit NPDES Permit
Department of Fisheries	Planting Fish Collectors (Scientific) Permits Aquaculture Operation Charter Boat License Handlers License Harvest Permit Commercial Fishing Licenses Hydraulics Project Approval

(continued)

Table 8-1. (Continued)

State agencies	Types of permits
Department of Game	Game Farmers License Permit for Planting Game Fish and other Wild Species Hydraulics Project Approval
Department of Highways	Approach Roads, Other Appurtenances Outdoor Advertising Permit Utility Franchise Utility Permits Merchandising Along Right-Of-Way Right to Back and Hold Waters Over Roads Mineral Lease Right of Way Cultivation Permit Log Tolerance Permit Special Motor Vehicle Permit Class A Additional Tonnage Permit Class B Additional Tonnage Permit
Department of Natural Resources	Mining and Mineral Leases Burning Permit Forest Practices Approval Dumping Permit Operating Permit Surface Mine Reclamation Permit Log Patrol License Oil and Gas Drilling Permit
Department of Motor Vehicles	Fuel Distributor's License Special Fuel Dealer, Special Fuel Supplier, and Special Users License Special Fuel Tax Single-Trip Permit State Registration of Land Development Camping Club Site Sales Temporary Interstate Permit Transportation of Logs
Parks and Recreation Commission	Sale of sand, lease and removal permits Parks and Recreation Facilities by a Port Permit for Improvement of Parks

(continued)

Table 8-1. (Concluded)

State agencies	Type of permits
	Safe and Adequate Ski Facilities and Equipment required of Owner and Operator
Department of Social and Health Services	Public and Semipublic Swimming Pool Construction Shellfish, Sanitary Control of Transit Accommodation Radiation Protection Licenses Public Sewage Disposal Public Water Supplies
Department of Labor and Industries	General Contractor License Specialty Contractor License Electrical Contractor License Journeyman and Plumbers License Electrical Permit Notification of Intent to Open a Mine
Washington Utilities and Transportation Commission	Register of Public Convenience and Necessity Single-trip Transit Permit Single-trip Regulatory Fee Card Storage Warehouses
Thermal Power Plant Evaluation Council	Thermal Power Plant Site Certification

its implementation; c) rectifying the impact by repairing, rehabilitating, or restoring the affected environment; d) reducing or eliminating the impact over time by preservation and maintenance operation during the life of the action; and e) compensating for the impact by replacing or providing substitute resources or environments." This definition of mitigation has been adopted by the USFWS.

Mitigation as defined above encompasses a diverse group of actions to avoid adverse impacts through land use planning, employment of specific actions to offset unavoidable adverse impacts, and enhancement of appropriate resources, both on- and offsite, to compensate for resource loss resulting from specific projects. Mitigation, although focusing on lessening the adverse impacts of proposed projects, nearly always results in a net loss of resources or options to manage those resources.

Long-term monitoring is an essential aspect of any mitigation program. Both biotic and abiotic components of the environment must be monitored throughout construction, operation, and close-out of a project. Only with accurate monitoring can the success of mitigation measures be evaluated or, if necessary, be restructured and redirected. Flexibility of a mitigation program should also be emphasized, as a rigid program would preclude any alterations deemed necessary by monitoring studies.

Fish and wildlife resources and habitat management practices resulting from energy development along the Columbia River Estuary will require a judicious choice of mitigating measures and techniques. Management strategies that enhance fish and wildlife habitat, are cost-effective, and may be applied to several energy-related developments, have been published by the Biological Services Program of the Fish and Wildlife Service (Nelson et al. 1976; Fore 1977; Dvorak and Lewis 1978; Galvin and Cupit 1979).

8.2 SPECIES-SPECIFIC GUIDELINES AND RECOMMENDATIONS

Management of fish and wildlife is accomplished using three general approaches, habitat management, species management, or most commonly a combination of the two. Protection and management of ecosystems, although ultimately desirable (Holt and Talbot 1978), has yet to be achieved. For rare, threatened, and endangered species, there are specific rules and protection regulations. For other species which are not specifically listed either by the federal government or the state, protection may be accomplished under more general federal and state environmental legislation or policy acts. For example, management and mitigation to protect species of concern in the Columbia River Estuary may be specific, as those proposed for the bald eagle and dungeness crabs, or very general, as those suggested for waterfowl and shorebirds. The preservation techniques suggested for some species have been successfully implemented elsewhere and show promise in protecting fish, wildlife, and habitat along the estuary.

Proposed recommendations are essentially oriented to species of concern. However, because many of these target species have general habitat requirements similar to several other species inhabiting the area and because other targeted species are excellent indicators of environmental condition, we believe the proposed management recommendations will help to assure the integrity of numerous nontarget species.

8.2.1 Fish

An important management and mitigation practice affecting fish inhabiting the lower Columbia River is the installation of fish passage facilities at dams. These include fish ladders and locks, powerhouse collection, spill, gatewell bypass, ice-and-trash sluice, and gatewell salvage systems. Each of these passage systems are discussed below.

Adult upstream migration at dams. Fish ladders are provided at all main stem Columbia River dams and at all dams above the Snake River up to the Rock Island Dam. All but one use a powerhouse collection system, which consists of a channel running across the dam face, with openings along its entire length. Fish that enter this channel via an opening are guided to the bottom of fish ladders. Fish locks exist at the Bonneville, Dalles, and McNary dams, but due to the relatively high efficiency of the ladders, the locks are not used. One dam, the Lower Granite Dam, has only one ladder on the south end of the dam; there is an entrance on the north end which channels fish over to the powerhouse collection system at the south end.

Downstream migration of juvenile fish at dams. Methods that facilitate downstream fish migration currently in practice in the Columbia River system include fish spill, gatewell bypass, ice-and-trash spill, and gatewell salvage systems. Some dams use a combination of these systems.

The fish spill system involves biosonar detection of juveniles behind the dam. When concentrations are detected, the spillways are opened, permitting the juveniles to pass over the dam. The major problem with this system is that it requires spillage of massive volumes of water, which at certain times of year may not be practical, and the number of fish passed may be limited. The Dalles Dam spill system is relatively efficient because of the unique placement of the powerhouse parallel to the river. This causes juveniles to concentrate heavily at the downstream end of the dam to later be passed through spillways in reduced volumes of water. The mortality rate in fish spill systems is rarely above three percent. It is estimated that at most dams no more than 50 percent of downstream migrants are permitted into spillways due to the limited water passage capacity.

During the process of improving turbine safety, juveniles which had entered the turbine intake housing were observed to concentrate near an access slot in the intake roof, and approximately five percent were observed leaving through the slot. Based on this observation, the gatewell bypass system was created. This involves a traveling screen, which is lowered into this slot and then raised, causing seven to eight percent of the juveniles present to exit via the slot. These fish are then diverted through a conduit to the tail race, or in the case of McNary, Little Goose, and Lower Granite dams, to a collection and transportation system, from which they are taken by truck or barge to a site below the Bonneville Dam and released. In 1980, an estimated seven to eight million juveniles were transported downstream by truck or barges.

Most dams were designed with a system to permit capture and removal of ice and trash which might accumulate on the upstream face of the dam. This ice-and-trash sluice system consists of a series of gates at the top of the spillways. Juveniles were observed to congregate at these locations, and presently approximately seven to eight percent of those concentrated are skimmed off and taken over the dams.

The gatewell salvage system is similar to the gatewell bypass system. Fish which enter the turbine intake have the opportunity to exit via openings in the gatewell. These fish are then passed out of the dam into the tail race.

A summary of upstream and downstream fish passage facilities at Columbia and Snake River dams is presented in Table 8-2.

The Columbia River Fisheries Council (1980) suggests a long-term management plan (20 years) to achieve goals for rehabilitating the local salmon and steelhead fisheries. The plan is stratified into five-year time frames with short-term actions prioritized within each interval. The highest priority action is to reduce mortality of juvenile downstream migrant salmon and steelhead trout. A maximum of 13 percent juvenile mortality at each main stem hydroelectric project is considered tolerable by the Columbia River Fisheries Council (1980). Reducing juvenile mortality on a short-term basis can be attained by increasing spillover and by altering flow regimes to optimize downstream passage. Long-term alleviation of this major problem must entail installation of more effective juvenile bypass systems at all main stem dams.

Salmon and steelhead production goals and strategies outlined by the Columbia River Fisheries Council (1980) include: 1) maximizing the production in the remaining natural habitat, 2) capitalizing on the production of operational and future hatchery programs, 3) compensating for salmon and steelhead losses at private and public utility districts and hydroelectric projects, and 4) rehabilitating natural habitats.

Thermal pollution is likely to result from cooling of power plants. Outfalls could be designed and regulated to achieve suitable temperatures for *Corophium* production, salmonid growth, and disease control. Outfalls could be designed using the principle of a soaker hose (many small holes along a pipe) to make a diffuse, small raise in temperature rather than one hot large plume. Cooling water may go through a cooling pond or a series of ponds, before release into the estuary. Temperature in the ponds could be monitored along with estuary temperature to allow optimal temperature adjustment at the outfall. If thermal cues are important to any specific organisms, this should be taken into consideration.

Management and mitigation for fish in the Columbia River Estuary must include maintenance and enhancement of water quality that considers such parameters as toxic elements and compounds, water temperature, dissolved

Table 8-2. Adult and juvenile passage facilities at Columbia River Basin dams.

Dams	Upstream migrant facilities (in use)	Downstream juvenile facilities/methods
Columbia River		
Bonneville	four ladders, two powerhouse collection systems[a]	gatewell bypass system
Dalles	ladders, powerhouse collection system[a]	ice and trash sluice system; very efficient for spill system (angle of dam across river concentrates juvenile at one end)
John Day	ladders, powerhouse collection system	fish spills, gatewell, bypass installed by 1985
McNary	ladders, powerhouse collection system[a]	gatewell bypass system to collection/transport system; juvenile brought by truck/barge to below Bonneville
Priest Rapids	ladders, powerhouse collection system	fish spills
Wanapum Rocky, Reach Wells	ladders, powerhouse collection system	none
Rock Island	ladders, large entrances at ends; no powerhouse collection system	none
Chief Josephs	none	none

(continued)

Table 8-2. (Concluded)

Dams	Upstream migrant facilities (in use)	Downstream juvenile facilities/methods
Snake River		
Ice Harbor	ladders, powerhouse collection system	ice and trash sluice system and fish spill
Lower Monumental	ladders, powerhouse collection system[a]	fish spills, gatewell salvage system
Little Goose	ladders, powerhouse collection system	gatewell, bypass system to collection/transport system, juveniles brought by truck/barge to below Bonneville
Lower Granite	ladders, powerhouse collection system at south end; entrance at north ends leads to powerhouse collection system	gatewell bypass system to collection/transport system; juvenile brought by truck/barge to below Bonneville

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[a] Have lock systems, but not used because of high efficiency of powerhouse collection system/fish ladder.

oxygen, pH value, and turbidity. Waterflow dynamics, substrate characteristics, and food availability for these fish must also be managed. General guidelines for management of these and other habitat parameters are given by Bell (1973).

Increased sewage and domestic pollution can be anticipated as a result of increased urban expansion in the Columbia River Estuary. At low concentrations sewage can provide nutrient enrichment, which will boost production of food organisms and eventually of salmon. Nevertheless, the hazard of oxygen depletion exists. Adequate flushing will prevent excessive concentration and eutrophication and can be assured by appropriate outfall location with respect to tidal and river current. Treatment plants should be equipped with sufficient storage capacity to allow release only under favorable tides, currents, winds, and temperatures.

Toxic substances also pose potential hazards for Columbia River fisheries. Using procedures similar to those mentioned above for sewage, mitigation would ideally entail onsite detoxification, then disposal, and finally dilution.

The detrimental effects of reduced genetic variability of Columbia River salmon populations due to propagation techniques in hatcheries may be partially alleviated by not selecting broodstock for clumped spawning and other practices. Broodstock should include a few outside fish to diversify the gene pool. The natural frequency of straying should be stimulated by this outbreeding. Precautions should be taken to assure that adaptation to a system is not sacrificed for too much genetic diversity.

Proper management of the harvest must be an integral part of achieving the goals of maintaining and enhancing the fisheries of the Columbia River Estuary (Columbia River Fisheries Council 1980; ODFW 1981). Any appropriate harvest scheme must include a cooperative effort between in-river and ocean harvest management. The Oregon Department of Fish and Wildlife (1981) stresses the importance of focusing management on individual stocks of fish and stock groups or units (a given species from closely adjoining river systems). They note that the application of the stock concept is essential for:"...1) conserving the gene pools of wild stocks, and 2) maximizing production of wild fish by providing for the maintenance and/or development of locally adapted stocks."

Problems resulting from a mixed ocean catch (native and hatchery stocks) are extremely difficult to resolve. The only possible apparent solution to this problem is to reduce ocean fishing and shift toward terminal fishery where stocks become better sorted out temporally and spatially. The problem may still remain with respect to the foreign ocean fishery since the United States has no control over this aspect of the harvest. In addition, this would restrict the American fishery with lower quality catch relative to the foreign fishery.

Dams have adversely affected white sturgeon populations by blocking adult migration to historic spawning areas. Viable upstream passage systems for adult sturgeon have not been developed, although extensive research has been conducted, primarily in the Soviet Union. Artificial propagation of white sturgeon should be considered as a feasible compensatory mitigation practice for the depleted fishery in the Columbia River Estuary (Clark, U.C. Davis Aquaculture Program Director; pers. comm.). Several publications by McGuire (1979, 1980, 1981) document the history and future of artificial propagation programs for white sturgeon.

8.2.2 Dungeness Crabs

Commercial and sport harvesting of dungeness crabs currently has the greatest impact on crab distribution and abundance. Thus the regulation of season, location, size limits, and other aspects of the crab harvest within and immediately off-shore of the Columbia River Estuary is the main management tool for protecting this resource.

Besides fishing, human-caused impacts to crabs, in decreasing importance, include those from dredging, industrial and agricultural runoff, and sewage effluents. Careful monitoring of crab populations is the first step in management and is necessary for establishing both impacts and potential mitigation measures. Suggestions for the reduction of dredge induced crab mortality include careful scheduling of dredging activities, using dredges that are least harmful to crabs, and physically modifying existing dredges to reduce crab entrainment and mortality. Seasonal variations in crab abundances within estuaries, and in different parts of the same estuary (Mayer 1973; Stevens 1981), suggest that crab mortality can be reduced through judicious choice of dredging activity. Mortality may further be reduced by using clamshell dredges which have been shown to be least harmful to crabs (Stevens 1981). Suction dredges have been implicated to cause the greatest harm, thus their operation should be limited to silty bottom sediments upriver, and other locations with low crab densities. Finally, modifications to existing dredges may reduce entrainment mortality. Stevens (1981) suggests that the removal of normal splash plates or their replacement with an alternative means of directing discharged sediments may reduce mortality. Additionally, the modification of dragheads on hopper dredges to deter and frighten crabs may be possible. Several other techniques show promise, but have not been investigated (Stevens 1981).

Industrial wastes, including heavy metals such as cadmium, silver, and selenium, have been found to concentrate in dungeness crabs (Wild et al. 1978). Lethal levels for 50 percent of the population within 96 hours were found to be 6.8mg/liter for cadmium and 0.19mg/liter for silver. Careful monitoring of effluents from energy developments is needed to insure compliance with existing laws. The effects on crabs of chlorine treated sewage effluent and petroleum hydrocarbons are under investigation. Their release from energy developments as well as their cumulative concentration should also be monitored. Insecticides, fungicides, herbicides, and other chemicals may be harmful to prozoeae, zoeae, and other larval developmental stages (Buchanan et al. 1970; Caldwell et al. 1978). Release or runoff of these chemicals is slight in the projected energy developments, although ROW management practices along transmission and pipelines will require careful monitoring of runoff, especially where these corridors cross streams, rivers, and aquatic communities.

8.2.3 Corophium Salmonis

Amphipod populations such as Corophium may be best protected by limiting habitat disturbance. Filling of the littoral and sublittoral zones for industrial and urban expansion causes the greatest immediate mortality and renders the fill area uninhabitable. Suffocation by dredge materials may further reduce their numbers. Disturbance of mud flats during the spring and fall may have the greatest adverse impact on Corophium because this is apparently the time when major recruitment occurs. Therefore, carefully planned dredging schedules together with disposal and upland sites would be a significant management mitigation measure to reduce mortality. Corophium occurs at very high densities in the substrate and waters of Youngs Bay and also inhabits the substrate of shallow waters of the estuary up to Portland and several Columbia River tributaries including Skipanon Waterway, Lewis and Clark River, and Youngs River. Monitoring at these locations should provide information on their population, and should enable timely mitigation in case of population declines. Production of Corophium can be enhanced through the proper management of thermal effluents as described in Section 8.2.1.

8.2.4 Waterfowl and Shorebirds

Waterfowl and shorebirds receive protection under the Migratory Bird Act. Mitigation and management practices include: furnishing wintering waterfowl with sufficient food and resting habitat to minimize mortality during fall and winter months, returning healthy birds to breeding grounds, and promoting feeding habitat for those species normally breeding in the Columbia River Estuary.

Management and protection of waterfowl and shorebird nesting habitat in the Columbia River Estuary are essential for the maintenance of local populations. Additionally, several approaches to enhance wetlands for breeding and nesting may be employed. Stabilizing water levels through diking of appropriate areas and creating subimpoundments may increase waterfowl productivity (Tabor 1976) as well as food production for several species (Chritiansen and Low 1970; Groen and Schroder 1978). Dikes and levees should be constructed using excavated materials from the project site, thus reducing the amount of unused spoils. Protecting dunes from urban development and recreational activities and ending the practice of dune stabilization would enhance this habitat for nesting shorebirds, including snowy plovers.

Tabor et al. (1980) proposed that water levels be elevated to peak flow levels at least every 3 to 4 days during daylight hours during the nest selection period for waterfowl to prevent their locating nests in areas subject to inundation from peak power flows.

Suitable nest structures can enhance waterfowl breeding in wetlands. This technique has been successful for wood ducks throughout the states (Bellrose et al. 1964; Grice and Rogers 1965) and in Oregon for hooded mergansers (Morse et al. 1969), common goldeneyes (Johnson 1967), buffleheads (Erskine 1972), and Canada geese (Reinecker 1971). Protection of existing islands and development of man-made ones can also enhance wetland shorebird and waterfowl productivity (Vermeer 1970; Hanson and Eberhardt 1971; Mickelson 1975; Giroux 1981). Construction techniques for nesting structures and islands can be found in USDA (1969), Jones (1975), Eng and Childress (1977), and USDI (1978). Waterfowl production can further be increased in many areas by using prescribed livestock grazing techniques at proper stocking rates (Sowls 1955; Anderson 1957; Martz 1967; Kirsch 1969; Gjersing 1971; Mundinger 1976). General considerations for management of livestock watering areas for waterfowl are given by Eng et al. (1979).

Management should, in part, focus on ensuring that sufficient quantities of quality food be maintained or increased for the numerous species of waterfowl and shorebirds using the Columbia River Estuary. Bellrose and Low (1978) have categorized three general management practices that may supply food to waterfowl. These are: "(1) seasonal manipulation of water levels, (2) impoundment and seasonal stabilization of water levels, and (3) agricultural manipulation."

Grain and food crops have benefitted several species of waterfowl in the vicinity of the estuary. These benefits, however, cannot offset the adverse effects of continued attrition of wetlands, marshes, and other riparian habitats resulting from agricultural and industrial expansion. Protection of amphipod populations such as Corophium salmonis and other naturally occurring food species will ensure the continued existence of shorebird populations.

Water quality must be maintained and upgraded to help alleviate the threat of mortality to waterfowl and shorebirds by toxic chemicals and waste materials. Management and mitigation for dealing with toxic chemicals and waste materials are discussed in Sections 7.3.

Waterfowl and shorebirds are also vulnerable to collisions with transmission lines and other man-made structures. Studies indicate that dabblers (Krapu 1974; Stout and Cornwell 1976), particularly green- and blue-winged teals (Anderson 1978), are more vulnerable to collisions with transmission lines than other waterfowl and shorebirds. Several mitigation actions to avoid, minimize, and compensate for collision related mortality have been suggested by Griffith (1977), Avery (1978), Meyer (1978) and James and Haak (1979). These include: (a) methods that simply avoid bird concentration areas in corridor selection, such as upgrading the existing system, removing conductors, not building, and/or creating load-center generation; (b) methods that adjust the right-of-way to reduce conflict, such as following and being compatible with existing barriers, scattering lines, and/or clustering lines; (c) methods that modify conductors and structures to reduce the probability of collision, such as diverting birds by modifying habitat and creating alternate habitat, placing lines underground, increasing visibility, changing conductor configuration, creating shelter belts, removing the static wire, repelling birds with corona noise and predator and distress calls, and controlling human access; and (d) methods that compensate for damage to bird populations, such as habitat enhancement at nearby unaffected locations.

Waterfowl management and mitigation practices should be guided by specific species behavior, habitat use, and requirements (Chapter 5). Salt, fresh, and brackish water marshes, and pasture land should be preserved for dabbling ducks. Deep water bays, estuaries, freshwater lakes, shallow marshes, and pools need to be protected for diving ducks.

8.2.5 Great Blue Heron

Management and mitigation practices affecting the great blue heron include protecting heronries and feeding areas by reducing illegal shooting and maintaining food availability.

Existing rookeries can be protected from disturbance by establishing buffer zones. These zones of 122 to 183 meters (400 to 600 feet) (Schlorff, pers. comm.) surrounding rookeries should be maintained whenever possible. The buffer zone should be established, depending on local conditions, by wildlife biologists, familiar with blue heron behavior.

The periphery of the rookery should be posted against trespassing. Herons are extremely wary and sensitive to human disturbance, particularly during breeding. Avoiding unnecessary disturbance between mid-February and mid-July can help guarantee productive Columbia River Estuary rookeries.

Resource agencies, such as the U.S. Fish and Wildlife Service, the Washington Department of Game, and the Oregon Department of Fish and Wildlife, review projects requiring federal or state permits for potential effects on great blue heron rookeries. Projects causing major disturbance to the rookery or buffer zone should be discouraged and only allowed if the potential adverse effects can be mitigated. For example, noisy construction activities should be prohibited adjacent to active rookeries during the nesting season.

Henny and Kurtz (1978) reported finding six great blue heron nests on channel markers in the Columbia River. These authors suggested that the unusual nest placement may have been in response to loss of nesting habitat created by flooding from the John Day Dam. The observations indicate that man-made nest structures may, in fact, serve as compensatory mitigation for degradation of a heronry. Henny and Kurtz (1978) suggest that artificial nesting structures be sited in isolated locations near an abundant food supply. Those over water should be at least 5 meters (16 feet) in height, and those along shorelines, even higher (Vermeer 1969).

Inter-tidal mudflats, estuarine marshes, and shoreline areas are favored feeding area for herons in the Columbia River Estuary. Major disruption or reduction of these areas should be discouraged.

Since herons are vulnerable to bioaccumulated toxins, maintenance of a toxin free prey item in these habitats is desirable. This is accomplished through strict enforcement of existing and future regulations of chemicals and toxicants. Water quality monitoring would identify potential sources of dangerous compounds.

Although herons are wary and adept at discerning potential danger, illegal shooting occurs. A public awareness campaign flyer with State hunting regulations, identifying herons along with other protected species, should be posted and distributed among hunters.

8.2.6 Western and Glaucous-Winged Gulls

The western and glaucous-winged gulls in the East Sand Island colony are at the limits of their respective geographic ranges and, therefore, may be more susceptible to changes in habitat, food, predation, etc. than populations centered in their range. For this reason, and for the fact that they represent a large, unique hybrid colony, these gulls may warrant special management attention. Yearly population censusing is essential so that the status of the colony can be determined and changes can be noted and assessed for probable cause. Management measures can then be implemented to reverse any potentially deleterious trends.

Management and mitigation measures for the East Sand Island gull colony may include the discouragement of extensive vegetation changes and/or harassment of the birds at nearby feeding, resting, loafing, and other essential nonbreeding areas.

Protective measures for the breeding birds could be initiated by posting of educational/admonitory signs; issuing special use permits for scientists, educators, photographers, bird banders, etc.; avoiding boat landings during the breeding season; and forbidding pets and the introduction of livestock or other grazers on the island.

Another measure includes regulating harbor maintenance (dredging) activities by: scheduling dredging and discharge to nonbreeding periods, advising the Army Corps of Engineers of seasonal breeding dates, habitat impact, etc.; initiating siting studies prior to discharge; requiring adequate diking to withstand slurry pressures; monitoring dredging activities to advise on potential danger to birds; and initiating follow-up studies to determine the long-range (vs. immediate) impact of dredging.

8.2.7 Bald Eagle

Bald eagle populations have experienced long-term declines due primarily because of the elimination and degradation of habitat and the killing of birds by shooting and poisoning. The Columbia River Estuary and adjacent region are used by bald eagles as wintering and nesting habitat. Site-specific management programs and recommendations have been suggested to minimize and offset human influence. Recommendations range from temporarily prohibiting human activities at sensitive eagle use locations to enhancing food and habitat characteristics. Specific programs suggested by several organizations (Snow 1973; Steenhof 1978; Krause 1980) and independent researchers (Servheen 1975; Grubb 1980; Stalmaster 1980) to protect nesting and wintering areas are described below.

The USFWS (1981) has delineated bald eagle nesting territories into two management zones, the primary zone and secondary or buffer zone. The primary zone is the most critical area around the nest, requiring maintenance to optimize conditions for eagles. Generally, the boundary of this zone shall not be less than 457 meter (1500 foot) radius from the nest site (USFWS 1978e). Adjustments to the actual size of the zone should be determined on a site-specific basis.

The USFWS recommends that there be no activity in the primary zone. The following human activities are likely to cause disturbance to eagles, and therefore, should not occur within the primary nesting zone at any time: 1) land use changes, such as logging, commercial and industrial development, construction and mining; 2) use of toxic chemicals, such as persistent organochlorine pesticides, PCB, mercury and lead; 3) human entry during the nesting period (except authorized eagle research and management activities with appropriate permits); and 4) low level aircraft operation within 500 feet vertical distance or 1,000 feet horizontal distance from an eagle nest. Human entry during the non-nesting period should be restricted to camping, hiking, picnicking, bird watching, hunting, fishing, and use of firearms should be regulated.

Essential research and management activities should also be restricted in the primary zone during the nesting period. Only those activities that are necessary for the protection or continued survival of the bald eagle and its habitat should be allowed, and they should be closely supervised and coordinated. No expanded human activity should occur in an area already receiving human use where a pair of eagles chooses to establish a new nest. The human activities occurring at that time may continue except for the use of toxic chemicals.

The secondary zone is established to buffer the primary zone and preserve potentially important suitable habitat for future use by eagles. The appropriate size of this area must be determined using site-specific criteria such as visibility from the nest, local topography, and proximity to feeding and other essential habitats. This area should have a minimum boundary of approximately 1,609 meter (1 mile) radius from the nest. The USFWS (1978e) maintains that certain human activities of a permanent nature are likely to disturb eagles and should be limited within the secondary zone. Their impacts increasing with the proximity to an eagle nest, these activities include, but are not limited to: the development of new commercial and industrial sites; the building of multi-story buildings, housing developments, new roads, trails, and canals facilitating access to the nest; and the use of toxic chemicals such as persistent organochlorine pesticides, PCB, mercury, and lead.

In general, no major activities should occur in this zone during the nesting period. Even intermittent use of activities of short duration are likely to cause disturbance. Examples are logging (including selective cutting), seismographic activities employing explosives, mining, oil well drilling, and low-level aircraft operations. Acceptable minor activities the birds will tolerate if restricted to the secondary zone include hiking, birdwatching, fishing, camping, picnicking, hunting, use of firearms, and recreational ORV use.

An example of the resiliency and opportunistic nature of bald eagles is their favorable reaction to the inadvertent increases of new habitat (nesting, feeding, and wintering) created by reservoir and dam outflows (Spencer 1976; Stumpf and Creighton 1977; Steenhof 1976; Lehman 1979). These observations suggest that enhancement of bald eagle habitat using actions similar to those mentioned above may be a limited, but viable, compensatory mitigation option for eagles. Although man-made structures such as dams have altered the distribution of bald eagles and possibly even benefitted some geographic populations, these changes more accurately represent an overall loss to the ecosystem (Olendorff et al. 1981).

Bald eagles have been documented by Dunstan and Borth (1970), Lamb and Barager (1978), and Postupalsky (1978a,b) to use artificial nests and nesting platforms. These structures may provide limited mitigation for a few projects.

Eagle perches and communal roosts can influence the distribution of eagles and ease winter maintenance of populations by facilitating food finding and providing protection from inclement climatic factors such as wind (Steenhof 1978). Management recommendations and mitigation actions must address protection of existing perch and roost locations and protection and enhancement of areas potentially suitable for expansion of these habitats. Recommendations by Steenhof (1978) for management of winter perches and roosts follow.

Diurnal Perches

Do not remove trees that are within 30 m (100 feet) of a river bank or lakeshore if they have diameters exceeding 30 cm (12 inches). These are usually preferred habitats.

Do not remove snags because they may be preferred perches in some areas.

Consider thinning young tree stands. Selective thinning stimulates growth of existing trees and creates openness around potential perch trees.

Create openings in dense stands. Trees interspersed with open areas are attractive to eagles.

Consider girdling a few trees to create snags in coniferous stands. Interspersed snags in coniferous stands provide the openness that eagles prefer. It is probably not necessary to deliberately create snags in deciduous stands because bald eagles readily use live trees when dead trees are not available. It is best to allow trees to attain maximum size before girdling.

Establish new trees in areas devoid of tree reproduction (especially along shorelines of newly established reservoirs). New plantings should be within 30 m (100 feet) of a bank. Cottonwood, maple, and sycamore should be the target species for management because of their suitable growth form. Cottonwoods are the best species to propagate in the Midwest because they grow rapidly and eagles prefer them.

Prune or graze saplings and young trees to stimulate forking, horizontal branch development, and the growth form preferred by eagles.

Do not depend on artificial perches to be effective replacements for natural wooded habitat. Artificial perches on bald eagle wintering areas thus far have been only partially successful. Experiment with unique perch designs, especially near feeding sites in treeless areas.

In areas where beavers are abundant and destructive, protect eagle perch trees by painting the trunks with creosote or enclosing them in 1 m (3 ft) high wire netting.

Communal roosts

Identify all communal roosts on the wintering area.

Determine the area needed to protect the roosts from human disturbance and habitat alteration. (For example, in South Dakota it was necessary to protect a stand of small trees on the bank that served as a wind barrier to roost trees.)

Eliminate existing threats to the roosting stand. (For example, riverbank stabilization was necessary in South Dakota.)

Make arrangements to preserve roosting stands through purchase, exchange, or cooperative agreements with either the private landowner or the government agency administering the land. The National Wildlife Federation, the Nature Conservancy, and the Audubon Society are possible funding sources. If purchase is not feasible, it may be desirable to buy an easement to protect habitat on private land.

Identify and protect potential roost sites on the wintering area. Wind protected valleys are good prospects for roost sites. Stands of large trees should be targets for development of roosts. The presence of one or two eagles may indicate the potential of alternate sites.

Create potential roosts in large dense stands by cutting a 30 m (33 yd) belt around a rectangular 5 ha (12 acre) stand of trees.

Establish new roosts in open, treeless areas by planting. Roosting stands should be 2 to 5 ha (5 to 12 acres), preferably rectangular. Establish windbreaks 30 to 50 m (100 to 170 feet) from the potential roosting stand.

Plan to develop potential roosts in all successional stages on the wintering area to ensure the presence of suitable sites for many years.

Food supply is a critical factor to wintering and nesting bald eagles. It is essential to minimize human disturbance at feeding areas, maintain and enhance present food supplies, and assure that food sources do not contain toxic chemicals. Artificial feeding programs may be justified when critical food shortages arise. An overview of management guidelines for bald eagle food supplies, most of which are applicable to the Columbia River Estuary, were listed by Steenhof (1978) as follows:

> Preserve and enhance populations of major fish species in the area. Salmon, goldeye, carp, shad, and bass are important target species. It is essential to ensure adequate reproducion for these species. Siltation from roads, logging, or overgrazing may interfere with reproductive success. The presence of gravel bars mixed with deep pools is critical for reproduction of many riverine species.
>
> Stock fish in small impoundments that do not presently support fish populations. Annual stocking of waters that freeze in winter will provide a source of winterkilled fish for eagles in spring and recreational opportunities in the summer.
>
> Manipulate water levels, where possible, to promote periodic stranding of fish. Use this option only when the practice does not threaten desirable fish populations. Artificial stranding in eagle wintering areas may be a potential tool for controlling trash fish.
>
> Discourage stream channelization efforts; preserve and develop winding, braided river stretches that facilitate stranding of fish. This is particularly important for fish species that spawn only once. It may be necessary to remove shrubby vegetation from stranding areas so that carcasses are visible to eagles.
>
> Consider artificial feeding programs using hatchery fish during unusually critical food shortages. Dead fish can be released into the river systems from hatchery holding ponds, and stored frozen carcasses can be deposited on open shorelines. This technique has been appropriate primarily on salmon spawning grounds during floods and serious fish population declines.
>
> Attract waterfowl to existing open water situations by habitat manipulation, including the establishment of food plots (e.g. fields of unharvested corn). The practice of baiting or other artificial means of attracting waterfowl should be discouraged. A small population of waterfowl will support several wintering eagles. However, since avian cholera and lead poisoning have both been diagnosed as causes of eagle mortality, managers should determine causes of waterfowl death before providing carcasses as a food source. The National Fish and Wildlife Health Labotatory should be contacted for diagnostic assistance and support. If waterfowl mortality is caused by an agent hazardous to eagles, an intensive program of carcass pick-up and disposal should be initiated, or the eagles should be denied use of this area.

> Support habitat improvement practices for upland game. Pheasants, cottontails, and jackrabbits are important alternate foods for eagles. Brushpiles, shelterbelts, and uncultivated fencerows provide good habitat for upland game. Areas of dense rank cover also provide habitat for upland game and should be preserved.
>
> Do not allow open bait trapping or use of poisoned bait within the area used by eagles. Eagles are attracted to these potential food sources and may be killed or injured. Scent traps are not directly hazardous to birds of prey. Healthy coyote populations can benefit wintering eagles because coyotes frequently open frozen carcasses and make them available to eagles.
>
> Leave deer carcasses on wintering site for future use by eagles. In emergency weather situations, it may be desirable to deposit additional carcasses. Local game wardens may have roadkills available for supplemental feeding.

In addition, the USFWS (1981) suggests the elimination of the use of persistent toxic chemicals (i.e. organochlorine pesticides, mercury, lead, PCB, etc.) in watersheds of lakes and rivers where eagles feed.

Studies conducted by Servheen (1975) and Stalmaster (1976) on the Skagit and Nooksack rivers in northwestern Washington documented the importance of natural spawning populations of salmon. Servheen (1975) stressed the significance of maintaining natural spawning populations and stated that "increased management efforts toward a large number of artificially spawned salmon are of no benefit to the eagles."

Incorrectly constructed or positioned power transmission lines can be hazardous to bald eagles. Placement of high voltage powerlines should not be within 1.5 km (1 mi) of communal roosts (Steenhof 1976). To decrease the incidence of shooting eagles, powerlines should be constructed at least 274 m (900 feet) from roadsides (Olendorff et al. 1981). Transmission lines not constructed in accordance with specifications given in Raptor Research Foundation (1975) and Olendorff et al. (1981) may cause electrocution of birds and, therefore, should be modified to meet these specifications. General mitigation measures to minimize collision related mortality of bald eagles and other birds are discussed in Section 8.2.4.

8.2.8 Columbian White-Tailed Deer

The primary goal of the Columbian White-tailed Deer Recovery Plan is to maintain a minimum of 400 deer, distributed in suitable, secure habitat within their former range in at least four viable populations (Martinsen et al. 1980). A clarification of the words "secure and viable" are given by Martinsen et al. (1980) as follows:

> "Habitat is considered to be secure only if it is virtually guaranteed to be free from adverse human activities (e.g., heavy grazing by domestic animals, clearing of woody plants, etc.) and is relatively safe from natural phenomena that would destroy its value to Columbian white-tailed deer.

> A viable population is one whose intrinsic probability of extinction is relatively low (i.e., independent of major environmental perturbations), as determined from annual estimates of population size (Gavin 1979), and whose population is large enough to minimize deleterious effects of interbreeding."

The Columbian White-tailed Deer National Wildlife Refuge in Wahkiakum County, Washington and Tenasillage Island, Clatsop County, Oregon are considered to be viable secure habitats and these areas supported 180 to 220 and 30 to 40 deer, respectively, in 1979. Three other populations thought to be viable, but not in secure habitat are those found on Puget Island, Wahkiakum County, Washington (30 deer); Wallace Island in the Westport area, Clatsop and Columbia counties, Oregon (30 to 50 deer) and; Douglas County, Oregon (Approximately 1,900 deer). The population of Karlson Island, Clatsop County, Oregon, is probably neither secure nor viable. Eight to twelve deer are thought to inhabit the island, which is subject to occasional flooding. Areas for consideration as critical habitat include:

> The Columbia White-tailed Deer National Wildlife Refuge (4,800 acres of mainland and islands).
>
> Specified lands adjacent to the refuge (1,090) acres), including portions of Hunting Island and Price Island.
>
> Puget Island and adjacent islands in Wahkiakum County (8,000 acres).
>
> Kerry Island and Magruder Ranch near Westport (1,500 acres).
>
> Wallace Island, Anundes Island area, Kinnunen Cut and adjacent shorelines in Columbia county (1,800 acres).
>
> Roseburg area, Douglas County (about 85,760 acres).

To achieve it goals, the recovery plan calls for developing and implementing a long-range deer management plan, encouraging cooperative agreements with landowners to adopt deer management and associated land use practices, formally recognizing critical habitats designated by the U.S. Fish and Wildlife Service, and developing public education programs.

To achieve the goal of four viable deer populations, transplanting should be considered. Possible transplant sites include Cottonwood Island (Cowlitz County, Washington) and Grim's Island (Columbia County, Oregon). The number of transplants should be at least four females and two males, and should be undertaken in spring. The potential for interspecific breeding of the white-tailed deer with the black-tailed deer should also be evaluated through field census and captive experiments. If hybridization is determined to be undesirable to the maintenance of Columbian white-tailed deer populations, then removal of black-tailed deer on the refuge from mid-October to late December should be considered (Martinsen et al. 1980).

The depletion of deer herds could be minimized or avoided by ensuring that development does not occur in prime deer habitat. The continual loss of interspersed woodland-grassland habitats should be avoided. Nonriparian locations would tend to avoid conflict with movement corridors within the floodplain. Studies early in the planning stages of management are crucial to optimal site selection and project mitigation. Mapping of prime deer habitats is required to alert planners to sensitive areas that are potentially unsuitable for development.

When habitat loss in unavoidable, compensatory measures include onsite or offsite habitat acquisition, improvement to unaffected habitat, or a combination of the two.

Site specific measures include such standard mitigation procedures as erosion control, revegetation of disturbed sites, the planting of preferred forage species, and control of encroachment, waste water, cooling discharges, and air emissions.

Public observation of Columbian white-tailed deer should be encouraged. However, vehicular and pedestrian traffic should be limited to the periphery of the refuge, thereby minimizing stress on the deer especially during winter and fawning periods (peak period may be mid-June) (Martinsen et al. 1980).

Following studies of Columbian white-tailed deer habitat use, Suring and Vohs (1979) concluded the management of grazing and vegetative cover can be used to manipulate the density and abundance of deer. Their recommendations for the Columbian White-tailed Deer National Wildlife Refuge include: (1) allowing growth of tall forbs to satisfy short-term cover requirements until long-term improvements to the forest communities can be accomplished; (2) planting native trees when woody cover is desired; (3) maintaining short vigorous vegetation growth in improved pastures through either grazing by cattle or mechanical means; (4) ensuring that sufficient high quality forage is available to deer in the fall by controlling cattle grazing; and (5) excluding cattle from approximately one-half of the woodlots thereby ensuring understory cover for winter and fawning habitats.

CHAPTER 9.0 PLANNING, POLICY, AND REGULATORY PROCESSES

Appropriate representation of fish and wildlife values in the development of energy related projects requires an understanding of the decision-making process which applies to such projects. The process is complex, involving numerous local, regional, state, and federal agencies and other public and quasi-public bodies. In order to achieve effective, timely participation in policymaking, planning, and regulation of energy related projects, concerned organizations must be informed of the mandates and avenues by which inputs may be made. This chapter reviews the policy, planning, and regulatory processes relevant to energy related development in the Columbia River Estuary.

9.1 POLICY AND LEGISLATION

Policy developed by local, state, and federal authorities broadly sets the context for energy development and concomitant environmental protection. Policy is expressed in legislative acts, executive orders, administrative procedures, ordinances, and enabling legislation for regulatory agencies.

9.1.1 Federal

Existing federal policy is expressed in a large number of legislative acts, executive orders, and agency administrative procedures. Major legislation concerning estuary management and conservation includes the Estuary Protection Act (P.L. 90-454), the Coastal Zone Management Act (P.L. 92-583), the Federal Water Pollution Control Act as amended (P.L. 92-500), the Fish and Wildlife Coordination Act (16 USC Sec. 661 et. seq.), the Endangered Species Act (P.L. 93-205), and the NEPA (P.L. 91-190). Federal Executive Orders include Protection and Enhancement of Environmental Quality (11514), Flood Plain Management (11988), Protection of Wetlands (11990), and Administration of Permit Programs - Water Pollution (11574). Procedures for management will be reviewed later in this chapter. In addition, individual agencies establish their own, more detailed policy guidelines for implementation of these legal mandates. The Pacific Northwest Electric Power Planning and Conservation Act of 1980 is the most significant of recent Federal policy actions.

9.1.2 State

Oregon and Washington have implemented state energy development policies through legislation, commissions, task forces, and energy facility siting councils. Oregon has been most active, with the establishment of a joint executive-legislative Energy Policy Review Committee, an Alternate

Energy Development Commission with task forces on hydro-electric, geothermal, biomass, gasohol, wind, and solar development, and an Energy Facility Siting Council (EFSC) with planning and site certification authority. The Council is staffed by the State Department of Energy, which also administers federal and state energy allocation, conservation, research, and development programs. There are also Governor's task forces on Offshore Continental Shelf Oil and Gas Development and Lower Columbia River Development. The latter, though not specifically energy oriented, has made recommendations for coal transshipment from the Astoria area (Tongue Point). Washington has a State Energy Office and a separately staffed EFSEC. This council lacks specific authority in anticipatory planning, but does strongly affect energy policy through its site certification decisions. It has been instrumental in reviewing development of an oil port on the Olympic Peninsula and in selecting a site for a coal fired power plant development at Creston, near Spokane, in preference to sites in western Washington.

Washington and Oregon have somewhat different state environmental policies. Washington has strengths in environmental assessment through the EIS provisions of the State Environmental Policy Act (RCW 43.21), and in management of almost all shorelines, through the Shorelines Management Act (RCW 90.54). Oregon is particularly strong in land use policy (Land Use Act of 1973, SB100) and in water resource policy and planning (ORS Chs. 536-540 relating to authority of the Water Policy Review Board and Water Resources Department). Both states are strong in implementing federal and state air and water quality laws and in coordinating environmental regulation through one-stop permit procedures (Washington EFSEC and Environmental Coordination Procedures Act (ECPA) of 1973; ORS Title 190 relating to the Intergovernmental Relations Division of the Oregon Executive Department). Both Washington and Oregon are relatively strong in the management of fish and wildlife, although control of activities impacting these resources is mainly accomplished through coordination with other agencies. The Washington Departments of Fisheries and Game (Hydraulics Approval Act, RCW 75.20.100) and the Oregon Division of State Lands (subject to approval by the Department of Fish and Wildlife, ORS 541) are responsible for regulating fill and dredge activities in waterways.

The management of state-owned lands in Washington and Oregon is guided by state constitutional directives, which in recent years has undergone new policy directives. These directives were established by such laws as the Washington Multiple Use Concept in Management and Administration of State Owned Lands (RCW 79.68.060), which directs the Department of Natural Resources to manage aquatic lands and certain other areas for multiple use. The ORS Titles 274 and 541 gives the Oregon State Land Board authority to manage and regulate submerged and submersible lands. Forest practices acts are in effect in both states.

Of particular importance for development in the Columbia River Estuary is Oregon's local comprehensive and coastal management planning policy. The 1973 Land Use Act (SB100) charged the Land Conservation and Development Commission (LCDC) with developing requirements and statewide goals and guidelines for coordinated land use planning. LCDC reviews and approves local plans on the basis of 16 state goals, four of which relate specifically to coastal and estuarine areas. Another goal (Goal 5) requires that local governments identify sites for energy resource development and reserve these sites, or institute a procedure for resolving conflicts among competing uses. In contrast, Washington has no comparable state policy concerning land use and planning. Localities are empowered to plan and zone, but receive little state direction apart from pass-through funding by the Planning and Community Affairs Agency. The Washington Shoreline Management Act of 1971 (RCW 90.58.020) established guidelines for planning and control on shorelines, which include all marine waters and significant streams and lakes.

The Oregon Economic Development Commission is authorized under ORS Chapter 184 to establish a comprehensive policy and plan for economic development in Oregon, particularly focusing on underdeveloped areas. This policy and plan are to be implemented by the Department of Economic Development (DED). The Oregon Ports Division (OPD) is now also under DED, where it will serve as coordinating, planning, and research agency for all ports and port authorities in the state. OPD's authority may also extend to port development, as indicated by DED's role in the state's recent purchase of a portion of Tongue Point from the Federal Government.

Washington has a Department of Commerce and Economic Development; however, it lacks a strong central policy mandate. In the 1970's the Department was decentralized into a number of separate service and assistance functions and grant programs. Within the Department, there is an office of Nuclear Energy Development which had been active in attracting nuclear industries to Washington, but now functions primarily as an information clearinghouse.

9.1.3 Local Government

Local government policy-making is tied closely with planning and implementation. Local government policies about the type and extent of desired development appear in policy sections of local comprehensive plans. The Columbia River Estuary Study Team (CREST) Plan reflects policies of Clatsop County, Oregon, the cities of Astoria, Warrenton, and Hammond, and the Port of Astoria in favor of port related industrial development (Bartl and Morgan 1981). This plan indicates the major interest of Pacific County, Washington and the Port of Ilwaco in servicing the small craft, sport, and commercial fishing industry in preference to industrial port development. Wahkiakum County, Washington has an explicit policy to encourage only small industries related to the county's natural resource base such as forestry, fisheries, and related riverfront activities including log storage, barge tie-up, marinas, and boat yards (Mathison, pers. comm.). Policy sections of Columbia County, Oregon Comprehensive Plan (1980), and the Cowlitz County, Washington Shoreline Management Water Program (1980) generally encourage the development of port related industry on large sites fronting the Columbia River ship channel.

9.2 PLANNING PROCESSES AND PROGRAMS

9.2.1 Local Comprehensive/Coastal Management Planning

Participation in local comprehensive and coastal zone management (CZM) planning and in single-purpose (categorical) planning of appropriate state, regional, and other federal agencies is probably the most effective way the USFWS can minimize the impacts to natural resources from future energy development in the lower Columbia Region. Through an understanding and a participation in the planning and regulatory processes, USFWS can help the other regulatory agencies gain an appreciation of fish and wildlife resource values. Needed energy developments will result in some resource losses, and the USFWS must be able to assess and accept mitigation and compensation. Regulatory action (e.g., permit review) is more direct, but because of its relatively incremental, reactive nature, it is of limited effectiveness in coping with the cumulative impacts of development expected to occur over the next 25 years. Planning and regulation are intended to be complementary, as, for example, in local planning undertaken pursuant to the approval of Washington or Oregon CZM programs, to which the requirements of the Federal CZM Act of 1972 apply. When this planning represents fish and wildlife values, it should provide direction and support for USFWS participation in regulatory actions, and allow USFWS to contribute to plan implementation.

9.2.1.1 CREST program. Continued active participation by USFWS in the CREST/CREDDP program is essential to insure that this planning effort will adequately represent fish and wildlife management interests. Subject to state approval, primary implementation of the CREST Plan will rest with its constituent local jurisdictions; in Oregon as part of comprehensive plans and ordinances, and in Washington as an update to existing Shoreline Management Master Programs. Implementation may employ all the regulatory tools available to local governments, such as zoning and subdivision ordinances, site development standards, or building and safety codes. Washington jurisdictions have the additional mechanism of the Substantial Shoreline Development Permit, required under the Shoreline Management Act. Capital development programs of local governments and port districts for service infrastructure, transportation facilities, and industrial site development must be consistent with these plans and ordinances.

Recognizing intergovernmental consistency requirements, the CREST organization (together with Technical Advisory Committees for state and federal agencies) will continue a cooperative management process that integrates local, state, and federal regulatory actions. The CREST Plan and local plans must be reviewed every two years by all agencies involved, and recommendations regarding needed changes in policies, land and water use designations, and regulations are solicited. Public and agency coordination meetings will be held during the review periods to achieve consensus on plan changes. A major plan review will be scheduled every six years for systematic analysis of the effectiveness of policies, plans, and regulations, and to incorporate new data from CREDDP and elsewhere, on any major plan change. Citizen involvement and local, state, and federal agency workshops will support this review (CREST 1979).

9.2.1.2 Wahkiakum, Cowlitz, and Columbia County Planning. The CREST planning program does not encompass the entire geographical area of concern in terms of energy related development that may impact the Columbia River Estuary. Wahkiakum County, Washington, which includes part of the estuary, has decided not to participate in CREST (CREST 1979; Mathison, pers. comm.). Much of the potential energy development that may occur in the lower Columbia region, however, will be upstream of the estuary proper, in Columbia County, Oregon and Cowlitz County, Washington (see Chapter 2). Participation in planning programs in these counties is also essential to estuary management.

Wahkiakum and Cowlitz Counties are subject to the Washington Shoreline Management Act, since the entire Columbia River is designated a "Shoreline of State Significance". The existing Wahkiakum County Shorelines Master Program is being updated, based partly on the CREST Plan and other information developed while the County was a CREST member (Mathison, pers. comm.). The Cowlitz County Master Program was recently updated (Deatherage, pers. comm.). Since these Master Programs are part of Washington's approved Coastal Zone Management program, Federal consistency requirements and guidelines for intergovermental coordination apply, as in the case of CREST. Thus, they should allow opportunity for continuing participation by Federal agencies in the updates. Wahkiakum County has no planning department and is being assisted in its Master Program update and in the preparation of a Comprehensive Plan by the Wahkiakum-Cowlitz Governmental Conference (the regional A-95 clearinghouse). Cowlitz County has an existing comprehensive plan which requires some changes to bring it into conformity with the Master Program (Deatherage, pers. comm.). Shoreline management planning has largely superseded conventional comprehensive planning along the Columbia River in these counties. Shoreline Management, with its permit system for substantial development, is a more effective mechanism for land use control, especially in unzoned areas (which include all of Wahkiakum County).

Columbia County is not within the area designated for Oregon's CZM program. The County has a Comprehensive Plan, dated 1980, which is required to conform to LCDC state goals and guidelines. Since the Columbia River in Columbia County is not defined to be estuarine, estuarine conservation goals may not apply (e.g., Goal 16 limiting dredging in estuaries to navigation or other water dependent uses; Goal 17 requiring water dependent use of shorelands). The plan does not appear to incorporate shoreline conservation elements comparable to the CZM plans of the other counties. Port related industrial development is given major emphasis. The County Planning Department and the Port of St. Helens are housed in the same building and appear to cooperate closely. Regulatory tools for implementing land use controls may be limited, since only small portions of the County are zoned, including incorporated areas (Christian, pers. comm.). This should not imply, however, that interests of Federal resource agencies are not considered or could have no influence on planning in Columbia County. The manager of the Port of St. Helens indicated that his organization desires better communication with USFWS and a clearer understanding of its concerns (Gainer, pers. comm.).

9.2.2 Other Planning Programs of State, Regional, and Federal Agencies

State and Federal agencies and the Pacific Northwest regional agencies and bodies are involved in various planning activities and programs that relate to energy development. Apart from participation in local/intergovernmental planning programs such as CREST, these agencies in general do not engage in comprehensive land use planning. Most planning activities are single-purpose or categorical (i.e., relating to one category of resource management, capital development, or regulation). Some partial exceptions to this include: state guidance of local comprehensive and coastal management planning (LCDC in Oregon is the only strong example of this); planning for the management of public lands dedicated to multiple uses, such as planning by Bureau of Land Management (BLM) under the Federal Land Policy and Management Act of 1976 and some state land management; and water resource planning by regional and state agencies.

Other state, regional, and Federal agency planning that is single-resource or single-purpose and relates to energy development includes planning for the management of oil and gas extraction (Federal and state lease programs); regional electric power planning and capital development; capital development and maintenance programs for highways, waterways, and other transport facilities; and economic development programs.

9.2.2.1 Planning for multiple use of public lands. BLM multiple use planning has limited applicability to the study area due to the small amount of onshore public domain land (BLM management of OCS areas is a separate issue). Of greater relevance is Washington Department of Natural Resources' (DNR) mandate under the Washington Multiple Use Concept to plan for multiple use of state owned aquatic lands. The administrative code reads:

> "The program is designed to provide for the best combination of aquatic uses and activities that are compatible yet minimize adverse environmental impacts. Under careful planning and multiple use management, a variety of uses and activities such as navigation, production of food, energy, minerals and chemicals, and improvement of aquatic plant and animal habitat can occur simultaneously or seasonally on Department of Natural Resource managed land suited for these purposes. This concept has incorporated in it the avoidance of permanent single-purpose uses on aquatic lands that have multiple use potential (except for reserves, harbor areas, and public places)." [WAC 332-39-100(3)]

Since Washington's state owned aquatic lands include all of the submerged area of the Columbia River and Estuary within the state boundary and not in federal ownership, these provisions offer an important tool for estuary planning - one that is given little attention in the CREST Plan. Public statements by the present administration of the Washington DNR indicate a commitment to implement policies for multiple use and balanced environmental management. Assuming that a planning process is instituted, control of energy development in aquatic lands may be a key issue, depending on the potential for extractive or other energy related use. Multiple use planning of these areas could be important for mitigation.

The Oregon Division of State Lands, Waterway Management Section, has similar regulatory authority for submerged lands, although there is no explicit mandate for multiple use planning.

9.2.2.2 Water resource planning. Water resource planning is single-resource by definition, but bears a close relationship to land use planning because of the interdependence of most land and water uses. Water resource planning is presently conducted at the regional level by the Pacific Northwest River Basins Commission in coordination with Federal, state, and local agencies, and at the state level by the Oregon Water Policy Review Board and Water Resources Department and by the Washington Department of Ecology.

The Pacific Northwest River Basins Commission is a Federal Interstate Compact organization established by Executive Order under authority of the Water Resources Planning Act (WRPA) of 1965. Its jurisdiction includes the entire Columbia River Basin in the U.S. and coastal drainages in Washington and Oregon. Under the WRPA, the Commission is directed to: coordinate federal, state, interstate, local and nongovernmental plans for water and related resource development; prepare a coordinated joint plan for water and related resource development; and recommend and conduct long-range programs of data collection and analysis. Further objectives adopted by the Commission in 1975 include: coordination of land use studies, determination of key areas for regulation, study of alternative growth patterns, coordination and assistance in developing interim management plans for the Columbia River Estuary (prior to implementation of CREST plans), coordination of recreation master planning, and preparation of an annual priorities report based on the coordinated joint plan and state water plans (CREST 1979). The relationship of river basin water resources to electrical energy development is recognized in the Commission's involvement in, and coordination of, regional power planning through its Power Planning Committee which prepares the annual report, Review of Power Planning in the Pacific Northwest.

Planning activities of the Pacific Northwest River Basins Commission are long-term and do not apply very directly to site-specific development control. Nevertheless, because this type of planning is based on interagency and intergovernmental coordination, it can have effects on the operational policies and objectives of agencies that do have specific planning, management, and regulatory authority. Since river basin planning is more open to interagency participation than the individual agencies' planning, it can provide a vehicle for USFWS to make its policies known, to communicate them to other agencies, and, thereby, to influence or become involved in the planning processes of other agencies. The coordinated joint plan is the focal point of the Commission's planning, since it sets allocation priorities and mediates among competing water uses, including hydroelectric power, fish, wildlife, industry, and domestic uses.

State water resource planning is intended to establish priorities for water use, providing a basis for the allocation, adjudication, or withdrawal from appropriation of surface and groundwater rights. The Oregon Water Policy Review Board and Water Resource Department are developing a water policy and plan for each basin of the state (the Columbia River minus its major tributaries is treated as one basin). The Water Policy Review Board may classify beneficial uses in a river basin and is directed to consider providing minimum streamflows for aquatic life -- though such a decision may only affect subsequent water rights (ORS 537.300, 537.310). When the Review board determines it is necessary to protect the public interest, it may withdraw a stream or a section of a stream from appropriation, after a public hearing (ORS 536.410). The Washington Department of Ecology is preparing a statewide water plan required to establish minimum streamflows and lake levels and to limit water permitting within these levels.

The Oregon Department of Water Resources (ODWR) and the Washington Department of Ecology (WDOE) each have the lead role in the respective state's approval of impoundments and hydroelectric projects; ODWR through licensing and WDOE through issuance of a water right, reservoir permit, and water quality certification. Administrative guidelines of both states require that concerns of their respective state fish and wildlife agencies be given high priority while considering water projects, issuance of water permits, and establishment of minimum flows/levels.

The Oregon Hydro Task Force in its 1980 report to the Governor, notes that the staff of the Oregon Department of Fish and Wildlife is too small to be effective in water resource planning or in the approval process for water projects. Increased staffing was recommended, although budgetary problems are likely to constrain implementation of this recommendation in the near future. Elsewhere in the report the parallel responsibilities of USFWS in reviewing water projects subject to federal licensing are also noted. Federal agency (USFWS or other) input is typically made through the federal licensor (e.g., FERC). The extent to which USFWS input might be welcomed by state water resource planners is unclear.

9.2.2.3 Oil and gas lease program planning. Oil and gas lease program planning, especially the Federal OCS program, is a complex process that is largely integrated with regulatory procedure. It is described in detail in Section 9.3.

9.2.2.4 Regional electrical power planning. Regional power planning has been mainly concerned with planning and scheduling of major, new generating facilities on the basis of working arrangements that have evolved between the BPA, public and private utilities, the WPPSS, and utilities planning councils, principally the PNUCC. The Pacific Northwest Electrical Power Planning and Conservation Act of 1980 establishes a new planning process which will profoundly affect power planning and resource development throughout the Pacific Northwest. An eight-person council appointed by the Governors of Idaho, Oregon, Montana, and Washington is charged to develop a regional "comprehensive power plan" within two years, and a plan to protect and enhance fish and wildlife resources in the Columbia River basin in one year. Both plans must rest heavily on a public input process which has as yet, in part, to be designed. However, this process will provide USFWS a highly significant opportunity to participate in decisions of great consequence to Columbia River fish and wildlife. The

Act gives BPA broad authority to acquire new power resources. BPA and the Council have already requested and received recommendations for the protection, mitigation, and enhancement of fish and wildlife resources in the Columbia River Basin from USFWS and other agencies (USFWS et al. 1981).

9.2.2.5 Transmission system planning. The BPA's capital development program for its transmission system is, and will probably remain, the major federal program in the lower Columbia River involving construction of energy facilities. This ongoing program is significant for the Columbia River Estuary because it plans and schedules development within the study area.

The BPA capital development program is tied to the federal budget, so that finalized planning and budgeting of projects must occur within a period of about two years prior to start of construction. BPA also has a long-term planning process, the basis for which is reflected in the Transmission System Facilities Ten-Year Development Tentative Forecast. The current document, for the period of 1980-89, presents specific detail regarding proposed development for each year. The document gives little attention to development alternatives and management/mitigation options. The introduction to the plan states that its purpose is to inform interested parties of BPA's projected new facilities, and that it is subject to change based on various facts, including information that may be developed in the preparation and review of environmental impact statements.

9.2.2.6 Channel maintenance and dredge disposal planning. Columbia River and Estuary channel improvements, dredge disposal, and related capital development and maintenance programs of the Corps of Engineers have important consequences for energy development. Dredging facilitates marine transportation and can create suitable shoreline industrial sites. Channel maintenance is an ongoing activity and requires ongoing planning. Studies have been conducted on future channel deepening and jetty improvements. Dredge disposal, however, requires a planning process, because new disposal sites must be selected as old ones fill in, and natural and man-made shoreline changes affect the physical dynamics of the estuary. Dredge disposal is guided by a Columbia River Maintenance Disposal Plan which is updated every few years. Localized modifications in the plan are made more frequently through public notices, several of which were issued in connection with the dredging required after Mt. St. Helens eruptions. In its introduction, the Maintenance Disposal Plan is described as a planning tool intended for dissemination to state and Federal organizations responsible for assistance and coordination of navigational maintenance dredging activities and subsequent material disposal.

9.2.2.7 Economic development programs. Economic development programs are an aspect of public planning related to the issue of energy development in the estuary. State and federal agencies and the Pacific Northwest Regional Commission encourage economic development through a variety of programs that fund or provide other resources or incentives to local governments, special districts, and the private sector. An increasing number of programs are energy related. Oregon's policy directive for the preparation and implementation of a state economic development plan was mentioned above. The current status of this planning effort in the Department of Economic Development (DED) is uncertain. Background studies such as the OPD (1980), however, have been prepared, and actions are being taken pursuant to the policy of assisting underdeveloped areas of the state. DED's purchase of former federal land at Tongue Point near Astoria, prospectively, to be made available for development of a coal transshipment terminal, is an example of unusually direct governmental action as a part of an economic development program.

9.3 REGULATORY PROCESSES

9.3.1 General

Regulation is one tool available to government for the implementation of policies and plans. Others include direct action such as land acquisition and management, capital development, program funding by other governmental entities, and tax incentives or other subsidies to the private sector. Unlike some tools that offer inducements, regulation is usually seen as a constraint or limit on private or public action.

Planning processes do not always exist in government to give long-term direction to regulatory actions specific to particular project proposals, sites, and times. Although both planning and regulation are found throughout government, the linkage is often missing or indirect, and the two types of activities frequently operate independently. In environmental regulation, some of the principal regulatory tools include environmental standards (e.g., air and water quality standards, zoning, building codes), licensing of certain facilities, permits for specified activities of many kinds, and environmental impact statements. All but the first of these types of regulation can occur independently of planning because they are only reactive.

This section describes regulatory responsibilities, procedures and actions that pertain to each type of energy facility development. Of particular importance are federal and state license and permit requirements that are energy-specific. Many environmental and land use regulations are not specific to any one type of energy or development, but must be satisfied by all developments having specified characteristics, activities, locations, or effluents. The following describes some of the most important areas of general regulation.

Permits issued by the U.S. Army Corps of Engineers under Section 10 of the River and Harbor Act of 1899 and Section 404 of the amended 1972 Federal Water Pollution Control Act are required for virtually all development activity on the shoreline of navigable waters. These waters include tidelands and wetlands. Permit application requires submission of a standard form accompanied by plans. For an energy facility, a public hearing would be held and an EIS would be required. USFWS reviews U.S. Army Corps of Engineers permit applications and EIS's under provisions of both the Fish and Wildlife Coordination Act and the NEPA.

Provisions of NEPA and the Washington SEPA require preparation of environmental impact statements for construction actions that significantly affect the environment. These are prepared by the responsible lead agency. Commonly they are first prepared in draft form by the applicant or a third party, under the agency's supervision.

The amended 1972 Federal Water Pollution Control Act addresses the discharge of pollutants into navigable waters and establishes the NPOES [33 USC 1311 (a)]. Discharges are allowed only if they are (1) in compliance with applicable effluent limitations established by the USEPA, (2) originated from new stationary sources designed and operated under Federal performance standards, (3) are consistent with existing water quality standards and toxic effluent limitations, and (4) are subject to pretreatment standards if introduced into treatment works (33 USC 1312-1317). NPDES permits are administered in Washington by the WDOE, and in Oregon by the Department of Environmental Quality.

Under the Federal Clean Air Act (42 USC 1857 et seq. as amended by PL 91-604), developments are required to comply with federal ambient air quality and performance standards. Similar provisions are found in state acts. Prior to construction of developments resulting in new contaminant sources, approvals are required pursuant to these acts. Air pollution regulation involves overlapping jurisdictions of the USEPA, state environmental agencies, and, in some areas, regional air pollution control authorities.

Under the Washington Shoreline Management Act (RCW 90.58.140), a substantial development permit is required for most nonresidential structures constructed in the shoreline zone, generally extending landward 200 feet from high water, or from the limit of a wetland, delta, or flood plain. The permit is issued by a local government, consistent with provisions of its approved Shoreline Master Program, and is subject to review by the WDOE.

Numerous other state environmental, health, and natural resource use permits may be required for energy development. Table 9-1 lists permits potentially required for hydroelectric projects in Washington. Most of these are general regulations, not limited to any one type of development. Included are state permits for development or fill/removal in state-owned submerged or submersible lands: in Oregon, a fill/removal permit issued by the Division of State Lands; in Washington, approval by the Departments of Fish and Game under the Hydraulics Approval Act.

Development must comply with local zoning, subdivision, and site development ordinances, and building, health, fire, and safety codes. Required approvals and permits include plat and drainage plan approvals, water supply approval, grading and building permits, sewage and solid waste disposal systems, and other permits.

Table 9-1. Possible permits required for small hydroelectric power projects in Washington.[a]

Permit	Agency and contact	Comments
Federal Permits		
FERC License	Federal Energy Regulatory Commission (FERC) (Quentin Edson - 101/376-1768)	License granted after review by other federal agencies.
Section 10 (Clean Water Act) or 404	Army Corps of Engineers (Gerry Keller - 206/764-3495)	Required for any activity in navigable waters.
State Permits		
Reservoir Permit (including dam safety approval)	Department of Ecology (Greg Sorlie - 206/753-6162)	For any man-made reservoir with a surface area over 40 acres or greater than 10 ft. in depth.
Permit to Appropriate Public Waters (Water right)	Department of Ecology (Greg Sorlie - 206/753-6162)	New water right required for energy generation. A change of use would require an Approval of Change of a Water Right.
Water Quality Certification	Department of Ecology (Greg Sorlie - 206/753-6162)	Triggered by FERC permit application for Dam Construction.
Flood Control Zone Permit	Department of Ecology (Greg Sorlie - 206/753-6162)	May be required if project is located within designated flood control zone.
NPDES or State Waste Discharge	Department of Ecology (Greg Sorlie - 206/753-6162)	Needed if pollutants will be discharged into surface or ground waters.
Sewage and Industrial Waste Treatment Approval	Department of Ecology (Greg Sorlie - 206/753-6162)	Sewage treatment or disposal system.
Hydraulics Project Approval	Fisheries and Game (Earl Finn or Chris Drivdahl - 206/753-3629 or 3319)	Required if structures are placed in the state's waters.
Public Water Supply Approval	Department of Social and Health Services (John Kirner - 206/753-5987)	If a public drinking water supply is needed or altered.
Lease of State Lands	Department of Natural Resources (Don McKay - 206/753-5328)	For structures on state land.
Forest Practices Approval	Department of Natural Resources (Don McKay - 206/753-5328)	For timber cutting.
Surface Mine Reclamation Approval	Department of Natural Resources (Don McKay - 206/753-5328)	If more than two acres are disturbed in one year.
State Environmental Policy Act (SEPA) Compliance	Department of Ecology and/or local Lead Agency (Greg Sorlie - 206/753-6162)	Will be completed upon issuance of final NEPA document by FERC.
Local Permits		
Shoreline Subtantial Development	County Planning Department	Required if project is located within local shorelines jurisdiction.
Various County Permits (Building, Plumbing, Grading, Zoning)	County Agencies	Depends upon specifics of project.

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[a] Source: Environmental Review Section, State of Washington, Department of Ecology, February 1980.

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9.3.2 Electrical Generating Facilities

9.3.2.1 General. Federal, state, and local governments have varied and increasing responsibilities for regulation of power developments. The differing roles of each level of government with respect to different types of energy development are largely the result of historical precedents.

For example, federal licensing of hydroelectric projects was established by the Federal Power Act of 1920, and has been a primary function first of the Federal Power Commission, and currently of its successor, the FERC of the U.S. Department of Energy. States have also taken a regulatory role in this area to varying degrees. Oregon licenses and certifies sites of hydro projects. Washington does not issue licenses as such, but has a coordinated permit process.

The Federal Government, through the Nuclear Regulatory Commission also licenses nuclear power plants, but there is no comparable federal role in the licensing of fossil-fuel thermal plants. The states have largely appropriated the area of thermal-electric facilities siting and site certification for both fossil-fuel and nuclear plants (hence a parallel federal and state approval process exists for nuclear plants).

Site approval and certification in both Oregon and Washington are accomplished through energy facility siting councils, but the states differ in approach and extent of their roles.

The Oregon EFSC is composed of appointed public members. It has a subtantial staff function in the Siting and Regulation Section of the State Department of Energy, and has authority not only over all types of thermal power, but also over hydroelectric plants, major transmission lines, pipelines, uranium processing facilities, and natural gas storage. The one-stop approval process is highly centralized. The Site Certificate is described as "an overriding permit, subject to a full litigation process" (Pollock, pers. comm.). The EFSC also designates suitable and unsuitable sites for large thermal plants and generally takes an active role in policy making and power planning.

The Washington EFSEC has minimal staff composed mainly of state agency representatives, but is not tied directly to any one agency. It has site approval authority over all thermal plants, but not hydroelectric plants. Although Washington's process is also described as a one-stop certification, EFSEC's role is more that of a coordinator among the various state agencies having regulatory authority. The EFSEC's approach is mainly a reactive one, responding to development proposals as they occur (Egbers, pers. comm.). Legislative authority and other information about the siting councils in the Oregon and Washington are given in Table 9-2.

9.3.2.2 Hydroelectric facilities - federal requirements. The FERC has authority to license all nonfederal hydro developments which are wholly or partially situated on federal lands, use surplus water or water from a Federal dam, affect interests of interstate commerce, or are on a navigable waterway.

Table 9-2. Summary of Washington and Oregon powerplant siting legislation[a], December 31, 1979.

Description	Washington	Oregon
Law No.	80,50RCW	Chap. 606, Oregon Laws 1975 (Senate Bill 483)
Date passed	Feb. 23, 1970; Amd. Mar. 19, 1976	July 1, 1975
Licensing body	Energy Facility Site Evaluation Council	Energy Facility Siting Council
Chairman	Appointed by Governor	Elected from membership
Membership	14 state agencies, 1 county member, 1 Port Commission member (when necessary)	7 members, all public
Staff director	Executive Secretary, Energy Facility Site Evaluation Council	Director, Department of Energy
Name of certificate	Certification	Site Certificate
Who must apply	All electric utilities	all electric utilities
Minimum plant size	250 mw per site (50 mw floating)	25 mw
Transmission lines	Associated T-Lines in excess of 200 kV	T-Lines greater than 230 kV
Application fees	$25,000 per plant application must approve expenditures beyond $25,000	$5,000 for Notice of Intent to file for large plants. Powerplant $0.05 per kW. Applicant must approve expenditures beyond $0.05 per kW and unspent money is refunded.
Annual fees	None	1 - powerplant $0.25 per installed kW. 2 - share of $20,000 based on annual kW hr.
Public hearing	1 - informational - within 60 days in the county of the site. 2 - formal - before Council recommendation to Governor. 3 - More, if necessary.	After application is filed.
Time limit for approvals	Council has 12 months for disposition followed by 60 days for disposition by Governor	1 - for large plants, file Notice of Intent. 2 - Application cannot be filed until 1 year after Notice of Intent. 3 - Council must act within 2 years after Application. 4 - Certificate cannot be issued until 3 years after Notice of Intent (unless waived). 5 - void if not signed by Governor within 30 days.
Unique features	A Council for the Environment is appointed by the Attorney General. Council reviews all applications for gas and oil pipelines, refineries, and terminals for LNG and oil.	Siting authority over all types of thermal power, hydroelectric power, pipelines, and nuclear installations. Council designates suitable and unsuitable areas for large thermal plants.

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[a] All sites require independent studies, monitor approval, and evaluation of the need for the facility.

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The interstate commerce provision is interpreted to the effect that a hydro project connected to a public utility system is involved in interstate commerce, so that such a project, regardless of size, is subject to FERC regulation. The navigable waterway provision incorporates any project on any waterway that is, or ever was, navigable. Consequently, few projects are entirely exempt from FERC regulation (Oregon Hydro Task Force 1980).

Various project categories, however, have different licensing requirements as follows:

> Projects greater than 1500 kW and involving an impoundment. Requires a major power license costing as much as $400,000 and requiring 15 months to 3 years to process. FERC license charges are based on the capacity and energy produced by a project and the cost of administration.
>
> Projects greater than 1500 kW at an existing dam. Separate licensing format but requirements similar to above.
>
> Projects less than 1500 kW and involving an impoundment, or at an existing dam higher than 25 feet, or impounding a reservoir less than 10 acres. Requires a minor power license.
>
> Projects less than 1500 kW at an existing dam less than 25 feet and impounding less than 10 acres. Short form license, minimal cost and time requirement.
>
> Projects less than 1500 kW in a conduit (e.g., irrigation canal or flume). Usually exempt from license. There is pressure on FERC to allow other exemptions. The Oregon Hydro Task Force recommends that all projects under 1500 kW be exempt unless FERC regulation applies because the power sold is involved in interstate commerce (Oregon Hydro Task Force 1980).

An application for a preliminary FERC permit or license establishes a priority among private applicants for that site. A public body has preference over private applicants and any other subsequent public applications for that site. An FERC license is normally issued for a period of fifty years. At the end of the license period, the project may be recaptured by the Federal Government or relicensed to the licensee (Oregon Hydro Task Force 1980). Litigation is underway to decide if the public preference for licensing also extends to relicensing (see Section 2.2.2.1, relicensing situation on the Lewis River).

In processing a license application, FERC must solicit comment from other federal agencies concerning the project's environmental impact, recreation values and impacts, and required permits. A draft EIS would normally be required to accompany the application. USFWS reviews FERC license applications and EIS's under provisions of the Fish and Wildlife Coordination Act and NEPA.

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If a hydroelectric project is on Federal land, the managing agency has licensing authority (in addition to FERC) under the Federal Land Act of 1977. The FERC license, however, generally preempts other federal agencies' right to control or regulate a project, and disputes between the licensee and another agency are decided by FERC (Oregon Hydro Task Force 1980). This preemption does not extend to Endangered Species Act provisions.

State requirements. State license, permit, and other requirements for hydro development are outlined as follows:

Oregon (Oregon Water Resources Department 1980)

1. State License Requirements

   a. Hydro projects are licensed by the Department of Water Resources.

   b. A license is required by all projects of any size. A major project is greater than 100 theoretical horsepower or where the applicant is a municipal corporation or qualifying utility district. A minor project is less than 100 theoretical horsepower, and involves simpler procedures.

   c. A major project license is issued for 50 years, a minor project license for 20. Minor project construction must begin within one year of issuance and be completed in three years.

   d. A license application is similar to a FERC application, and can use much of the same material.

   e. Filing and annual fees are based on theoretical horse-power.

   f. State agencies review the application. The opinion of Oregon Fish and Wildlife Department is considered critical because mitigation measures may be required.

   g. No EIS is required.

2. Water Use (Water Right)

   a. The applicant files with the Water Resources Department.

   b. The principles of the "first in time-first in right" and "use or lose" applies.

   c. A water use authorized by a power license is concurrent with the license period.

   d. The state's water use provisions and designations control all projects. These include extensive prohibitions against use of water for hydro generation in many areas, based upon the proposed size of the project and/or its general location.

3. State Siting Authority

   a. A site certificate from the Energy Facility Siting Council is required if installed capacity is 25 MW or greater.

Washington (Egbers, pers. comm.)

1. No state license or site certification is issued.

2. A reservoir permit and dam safety approval is required from the WDOE for reservoirs over 40 acres in surface area or 10 feet in depth.

3. A new water right is required from WDOE.

4. An extensive list of permits is required from state agencies (see Table 7-1). At the applicant's option, WDOE will coordinate permit application under the ECPA one-stop process.

9.3.2.3 Thermal-electric facilities - federal requirements. The National Regulatory Commission preempts authority to license all nuclear power plants. Decision on a license application is made by the National Regulatory Commission Atomic Safety and Licensing Board after extensive public hearings, review by government agencies, and evaluation by the Board and National Regulatory Commission staff. This process takes a minimum of two years, and often much longer.

State Requirements. In Oregon, site certificate from the EFSC is required for thermal plants of 25 MW or greater installed capacity, and for associated transmission lines greater than 230 kV (see Table 9-2; also Oregon Administrative Rules, Chapter 354, Energy Facility Siting Council, Division 25, Information to be Furnished in an Application for Site Certificate for a Nuclear Fueled or Coal Fired Thermal Power Plant; and Division 26, Construction and Operation Rules for Thermal Power Plants, June, 1980).

In Washington, certification by the EFSEC is required for thermal plants of 250 MW or greater per site, and for associated transmission lines greater than 200 kV (Table 9-2).

9.3.3 Processing Facilities

9.3.3.1 Refining. In Washington, new refining capacity, as well as oil terminals and pipelines larger than certain defined thresholds are treated under the 1975 Energy Facility Siting Act (RCW 80.50) as major energy facilities. These are defined to include: (1) petroleum refineries capable of processing more than 25,000 b/d; (2) crude or refined petroleum receiving facilities handling over 50,000 b/d when the substances have been, or will be, transported over marine waters; and (3) oil pipelines larger than six inches inside diameter and at least 15 miles long. Also included are associated storage and handling facilities associated with these. Existing refineries are exempted on the basis of prior use, but applicants for new construction permits appear before the Washington EFSEC. As outlined in Table 9-2, the EFSEC is composed of state agency heads, most with permitting authority. If a majority of the Council recommends site approval to the Governor and he signs it, a one-stop certification in lieu of separate agency permits is issued. A representative of the affected county sits as a voting member. Hearings are conducted publicly as contested actions. The applicant pays the cost of consultants and investigation, including preparation of the draft EIS under SEPA.

In Oregon, the EFSC issues site (i.e., corridor) certificates for oil pipelines above a capacity determined by formulae, but not for refinery terminals or tank farms. Required permits from the Department of Environmental Quality, the Water Resource Department, and other agencies must be applied for individually.

9.3.3.2 Liquified Natural Gas (LNG)/Liquified Petroleum Gas (LPG). The various federal agencies involved with the regulation of LNG and LPG and their authorities are summarized in Table 9-3.

In Washington, the Energy Facilities Siting Act governs: (1) the siting of LNG marine receiving facilities with a capacity over 100 million cfd of natural gas (after gasification); (2) LPG receiving facilities handling over 50,000 b/d when the LPG has or will be transported over marine waters; (3) underground reservoirs for natural gas storage capable of delivering 100 million cfd; and (4) natural gas, synthetic fuel gas, or LPG pipelines larger than 14 inches in diameter and at least 15 miles long when such pipeline delivers to a distribution facility, except when it involves interstate commerce and is regulated by the FERC (RCW 80.50, 1975). As with other facilities addressed in the act, the EFSEC receives and evaluates applications and makes recommendations to the Governor for approval or denial of certification.

In Oregon, efforts are underway to extend jurisdiction of the State's Energy Facility Siting Act to require site certificates for LNG facilities. The law currently applies to gas pipelines and related facilities where pipelines are larger than 16 inches in diameter and over five miles long. A variety of individual agency permit requirements pertain. As with other types of energy facilities, the Oregon Land Use Act requires that, in the absence of approved local plans, state agencies apply the LCDC State Goals in evaluating permit applications.

9.3.3.3 Synthetic fuels. As yet there appear to be few regulatory controls specific to synfuel production, although such regulations are likely to emerge in the near future. Existing environmental controls and permitting at federal, state, and local levels apply. It is uncertain whether a synthetic fuel plant would come under the authority of the Washington Energy Facility Siting Act. A synthetic oil production facility might be considered a refinery, and, if so, would be subject to the Act if it had a production capacity of more than 25,000 b/d. A synthetic gas plant would not seem to come under any provisions of the law. The Oregon

Table 9-3. Federal agency controls over LNG and LPG facilities and transportation in 1982.[a]

Agency	Statutory authority	Process	Concerns
Department of Energy including Federal energy Regulatory Commission and Economic Regulatory Administration (LNG)	Department of Energy Organization Act of 1977; Natural Gas Act of 1938 NEPA	Certification or approval: by Secretary for ¶3 (imports and exports); by FERC for ¶7 (interstate commerce)	Meeting Federal safety regulations prescribed by MTB: Environmental effects, via (1) EIS, including risk, analysis, guidelines concerning aesthetic, recreational, historical, archaeological, fish, wildlife and landscape values; Economic effects, including gas pricing and market control; Consistency with state and local land use, zoning, energy and other laws
Department of Transportation, Materials Transportation Bureau (LNG and LPG)	Natural Gas Pipeline Safety Act of 1968 Hazardous Materials Transportation Act	Inspection of facilities before and during operations (Washington Utilities and Transportation Commission is responsible for enforcement of pipe-regulations)	Safety on land through fire hazard regulations such as set back, diking, back-up systems and the safety of related facilities; regulation of pipeline facilities (natural gas)
Department of Transportation, Coast Guard (LNG and LPG)	Ports and Waterways Safety Act of 1972 (including 1978 amendments); Executive Order 10173; Dangerous Cargo Act; Magnuson Act	Inspection of vessels during construction or upon entry into U.S. waters; Issuance of Letter of Compliance or Certificate of Inspection (good for two years); Restriction and regulation of vessel movement; Inspection of waterfront facilities and facilioperations; and Hazard containment, prevention and control	Safety at sea: design and construction personnel navigation, safety pollution control equipment cargo stowage vessel traffic control Safety at Waterfront facilities: proper securement of vessels for cargo transfer proper communication between vessel and terminal during transfer safety equipment and procedures at facility personnel qualifications
Department of Army, Corps of Engineers (LNG and LPG)	Rivers & Harbors Act; Fish & Wildlife Coordination Act; NEPA: Federal Water Pollution Control Act Amendments of 1972	Permit for activities affecting navigable waters; EIS for major and significant actions; Comments from NOAA, U.S. Fish & Wildlife Service, EPA and state and local agencies	Environment; Economics; State and local wishes; "Overall public interest"

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[a] It is expected that the 96th Congress will consider legislation that could significantly extend federal jurisdiction over LNG and LPG transport and facility sitings.

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Siting Act does not cover either type of facility. In both states, however, oil or gas pipelines extending from these facilities might be subject to certification, and the facilities themselves might be construed as integral with pipeline systems.

9.3.3.4 Biomass conversion (alcohol fuels). The only special regulatory requirement for production of alcohol fuels is a license from the Federal Bureau of Alcohol, Tobacco, and Firearms. All other standard environmental controls and permit requirements apply. Federal and State tax credits and other incentives have recently been established to encourage development of alcohol fuel production.

9.3.3.5 Nuclear fuels and waste. All processing activities are controlled by the Nuclear Regulatory Commission. In Oregon, the siting of uranium mills and processing facilities is covered by the Energy Facility Siting Act, and is the responsibility of the EFSC.

9.3.4 Transportation and Transshipment Facilities

Commercial interstate transportation is regulated by the Interstate Commerce Commission. The development of transportation facilities is regulated through a variety of license and permit processes, depending on the type of facility. The construction of gas pipelines is regulated and licensed by the FERC. The states, through their energy facility siting councils, certify power transmission lines and oil and gas pipelines. This authority, however, has not yet been tested for coal slurry pipelines.

Port development and channel improvements require dredge/fill permits from the U.S. Army Corps of Engineers and either a fill/removal permit from the Oregon Division of State Lands, or approval from the Washington Departments of Fisheries and Game. Development of ports and other transportation facilities is also subject to local land use regulation. Major changes or additions to the highway or rail systems would require various approvals at the federal, state, and local level. Transportation planning is normally included as a major element within the Comprehensive Plans of local jurisdiction.

9.3.5 Extraction

9.3.5.1 Federal jurisdiction. The Federal Government retains all mineral rights and controls extraction activities (generally through leases) on Federal lands onshore, and on the OCS beyond three miles from the coast. The federal lands in the Lewis and Clark and Columbia White-Tailed Deer Refuges on the islands of the Columbia River Estuary constitute a situation of onshore federal lands with a potential mineral energy resource. The following discussion relates to the offshore federal jurisdiction.

The OCS program is a function of the U.S. Department of the Interior's BLM. The BLM has three mandated objectives: (1) orderly development of the shelf's resources, (2) protection of the environment, and (3) receipt of a fair market value for exploration rights and for oil and gas produced. BLM has established a schedule for phased leasing of selected offshore areas of the U.S. Continental Shelf, based on estimates of resource potential prepared by the USGS and by oil companies. This schedule emphasizes leasing areas with the highest probability of commercial quantities of oil and gas. Prior to 1977, the Oregon/Washington continental shelf was listed in the schedule. However, this region was dropped entirely from the timetable (OSU Sea Grant 1978), and is not shown in the most recent version of the lease schedule published by BLM in 1980, because industry had ranked it lowest among all the areas in terms of resource potential and desirability for leasing.

After a schedule is issued, the USGS gathers further data on the possible mineral resources in the areas considered for leasing. Oil companies and geophysical survey firms often participate in such data collection, but make their own interpretations. USGS resource reports examine the marine resources that OCS development may affect, and other federal agencies comment on the proposed lease areas.

Each OCS sale area in the leasing schedule is divided into three-mile square tracts. When BLM issues a call for nominations, oil companies respond by naming tracts they would like to lease for exploration and development, based on results of their initial geological surveys. At this point, other federal agencies, state and local governments, interest groups, and individuals can nominate tracts they would like excluded from leasing. Once all nominations are received, the BLM decides which tracts to lease, based on resource potential, environmental criteria, and the expressed interests of all concerned parties.

Once tracts are selected, another series of studies of the marine environment is undertaken to establish a bench mark against which impacts of OCS development can later be measured. Studies include weather patterns, ocean currents, seafloor sediments, seawater chemistry, and biota present at each tract. Using this information, BLM prepares a draft EIS for the tracts. Inputs from federal, state, and local agency review and public hearings are incorporated into a final EIS. The Secretary of the Interior reviews the EIS and other information and advice, and decides whether or not to hold a lease sale for the chosen OCS tracts.

If the decision is to proceed, BLM publishes a notice of the lease sale and establishes its terms. The USGS prepares estimates of the value of mineral resources contained in the tracts. Interior awards the lease of each tract to the highest bidder, but may reject all bids if they do not reflect fair market value and may reschedule the lease for a future date (OSU Sea Grant 1978).

Successful bidders have the right to explore for five years. If oil or gas is found, a firm has production rights for as long as production continues. If no commercial discovery occurs in five years, companies must terminate the lease. The federal leases off the Oregon coast that resulted in the unsuccessful 1964-65 explorations were terminated in 1966 (OSU Sea Grant 1978).

This lease process may be repeated several times in an area. The fact that leasing occurred off the Oregon coast in the 1960's does not preclude a repeat of the lease process for the same area.

Various federal agencies supervise all phases of OCS exploration and development. The USGS reviews and approves exploration plans, issues drilling permits, monitors drilling procedures, reviews plans for development and applications to drill production wells, and checks system components prior to installation. The USEPA issues pollution control permits. The U.S. Army Corps of Engineers and the U.S. Coast Guard regulate navigation. The U.S. Coast Guard also has jurisdiction over oil spills in coastal waters; however, some elements of this jurisdiction are shared jointly with the state environmental agencies in Oregon and Washington.

Other federal regulations apply to pipelines and onshore OCS related facilities. Pipelines used to bring natural gas ashore, if connected to the interstate network, would come under FERC regulation. The U.S. Army Corps of Engineers, USEPA, and other federal permit requirements and reviews would apply to most onshore facilities.

Recent amendments to the 1953 OCS Act and the Coastal Zone Management Act (CZMA) of 1972 provide funding to coastal states and localities affected by OCS and other coastal energy activities. The Coastal Energy Impact Program (CEIP) is administered through the Office of Coastal Zone Management (NOAA Department of Commerce). Under Section 208 of the CZMA amendments (1G U.S.C. 1451, et. seq.), a total of $1.2 billion in grants was authorized for a ten-year period that started in 1976, for planning, financing of public facilities and services, and prevention, reduction, or repair of damage to environmental or recreational resources (e.g., oil pollution) resulting from coastal energy activity. Coastal energy activity is defined as: OCS energy activity; coast related transport, storage, or processing of LNG; and coast related transport or storage of coal, oil, or natural gas. Thus CEIP is largely but not exclusively OCS related. Grant funds can be used to plan and prepare for non-OCS energy activities and facilities impacting the coastal zone. Oregon and Washington are not eligible for a portion of the planning funds since they are already receiving funds for implementation of CZM programs under Section 306 (CEIP Proposed Rules, Federal Register, October 22, 1976).

9.3.5.2 State Jurisdiction. The states of Oregon and Washington retain mineral rights and control resource extraction on state owned lands onshore and submerged lands including the beds of navigable rivers, tidelands, and offshore submerged lands extending to the three-mile limit. The Federal Submerged Lands Act of 1953 made clear that coastal states were entitled to control the waters and submerged lands three miles seaward of their coastlines (OSU Sea Grant 1978).

In both Oregon and Washington, state lands are managed under state constitutional requirements to produce income (principally for state school support) through the leasing of lands for commercial timber production, agriculture, and other activities including mineral extraction.

In Oregon, state lands are managed by a State Land Board composed of the Governor, the Secretary of State, and the State Treasurer. The Land

Board sets policy and issues directives to the Division of State Lands (DSL). Mineral leasing involving shoreline, waterway, submerged, or offshore areas is handled by the Waterway Section, which also makes determinations of waterway navigability and title, administers a state removal/fill permit system, and develops river bank structure standards for the Columbia River to minimize damage from ship surge and wakes (Oregon State Land Board and Division of State Lands 1979).

In Washington, state land management is the responsibility of an elected Commissioner of Public Lands, who interprets constitutional directives, largely independent of either executive or legislative policymaking. The Commissioner's land management decisions are implemented through the DNR. Mineral leasing, both onshore and in submerged lands, is handled by the DNR Division of Public Lands.

Both states have geological resources agencies that conduct some limited investigations of oil and gas resource potential and work with the land agencies in developing mineral lease programs: in Washington, the DNR Division of Mines and Geology; in Oregon, the Department of Geology and Mineral Industries.

The leasing provisions of Washington provide for an initial five-year term. If production of commercial quantity is begun within that period and continued, the lease can be extended for up to 20 years, not including periods of inactivity between the termination of production from one well and the start-up of another (Washington DNR Oil and Gas Lease standard form revised July 1980). This initial lease term in Oregon is ten years (Hamilton, pers. comm.).

Both states employ a public bonus-bid process for awarding most leases, replacing what had been a first-come, first-served method of issuance. Cash bonuses are offered by applicants in sealed bid auction. The amounts of these bonuses vary greatly, depending on the competitive situation.

Oregon prohibits drilling through a water column; this is an explicit policy of the State Land Board (Hamilton, pers. comm.). In Washington, the standard lease agreement states that no drilling is allowed in lakes 20 acres or larger or streams of 20 cfs or greater flow, or within 1,000 feet of the high water mark of such water bodies. There is no apparent prohibition on drilling in marine tidelands or waters of Washington, except in Puget Sound. At what point in an estuary the stream provision would cease to apply is unclear.

State authority also applies to extraction activity wherever it occurs within a state's jurisdiction, whether on public or private lands. Energy facility siting councils in both states would have to certify in-state oil and gas pipelines, which could effectively control development of an oil or gas field. Any major production facility might fall directly under this siting authority; this has been claimed for offshore as well as onshore structures in Oregon (OSU Sea Grant 1978).

The Oregon Department of Geology and Mineral Industries sets regulations for the extraction of mineral resources and issues permits for drilling operations. The Oregon Department of Environmental Quality and the Washington Department of Ecology ensure compliance with federal and state air and water quality regulations, including issuance of NPDES permits.

Some of the other state requirements are set forth in the Washington DNR lease agreement form. They include preparation by the lessee of an Environmental Protection Plan stating measures to be taken for noise and dust control, prevention of water pollution, control of drilling mud, provisions for natural vegetative screening of the drill site, setbacks from water bodies, and other procedures. If development entails significant environmental impact according to SEPA guidelines, EIS preparation may be required as an adjunct to DNR's lease actions.

Onshore extraction activity and associated development would also have to conform, or be reconciled, with local plans and zoning, as an extractive use (the common zoning term), an industrial use, or under special provisions or use permits. Experience elsewhere in the country indicates a strong tendency for local accommodation of energy resource extraction, recognizing the site-specific nature of these opportunities.

Although states and localities do not have direct control over OCS resource development beyond the three-mile limit, they do have authority to control associated onshore support development, and to plan for and accommodate impacts, using the CZM and CEIP funding described earlier. More importantly, because both Washington and Oregon have approved CZM programs, Federal actions in or near the states' coastal zones, including OCS, must be consistent with state goals and standards expressed in these programs, and with local plans developed under them.

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APPENDIX A

COMMUNITY COMPOSITION - RIVERINE HABITAT

COMMUNITY COMPOSITION INLANDS   ZONE: WESTERN HEMLOCK   HABITAT: RIVERIN-

TROPHIC LEVEL: (1) PRODUCER
NON-VASCULAR PLANTS

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
ACHNANTHES AFFINIS DIATOMS	Q	-
ACHNANTHES DEFLEXA DIATOMS	Q	-
APHANIZOMENON BLUE-GREEN ALGAE	C	-
CYMBELLA VENTRICOSA DIATOMS	Q	-
DIATOMA DIATOM	C	-
DIATOMA HIEMALE DIATOMS	Q	-
DIATOMA VULGARE DIATOMS	Q	-
MELOSIRA DIATOM	C	-
NAVICULA DIATOM	C	-
NITZSCHIA DIATOM	C	-
OSCILLATORIA BLUE - GREEN ALGAE	C	-
PINNULARIA DIATOM	U	-
SPIROGYRA GREEN ALGAE	C	-
TABELLARIA FENESTRATA DIATOMS	Q	-
TABELLARIA FLOCCULOSA DIATOMS	Q	-
TETRASPORA GREEN ALGAE	Q	-
ULOTHRIX GREEN ALGAE	Q	-

TROPHIC LEVEL: (1) PRODUCER
VASCULAR PLANTS

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
POTAMOGETON ALPINUS MOUNTAIN PONDWEED	U	-
POTAMOGETON FOLIOSUS CLOSE - LEAVED PONDWEED	C	-
RORIPPA NASTURTIUM AQUATICUM WATER - CRESS	C	-

Abundance codes: A=abundant, C=common, U=uncommon, Q=present abundance unknown
Status codes: R=rare, E=endangered, T=threatened, P=peripheral, I=endemic, G=game
C=commercial and potentially commercial, X=pest

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COMMUNITY COMPOSITION INLANDS   ZONE: WESTERN HEMLOCK   HABITAT: RIVERINE

TROPHIC LEVEL: (2) HERBIVORE
INVERTEBRATES

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
ALLOCOSMOECUS CADDISFLIES	A	-
AMIOCENTRUS CADDISFLIES	A	-
BAETIS MAYFLIES	A	-
BORECCHLUS TRUE MIDGES	Q	-
BRACHYCENTRIDAE CADDISFLIES	C	-
BRACHYPTERA STONEFLIES	C	-
BRILLIA MIDGES	C	-
CHIRONOMIDAE TRUE MIDGES	A	-
CINYGMULA MAYFLIES	A	-
CLADOTANYTARSUS TRUE MIDGES	Q	-
CRICOTOPUS TRUE MIDGES	C	-
ELMIDAE RIFFLE BEETLES	A	-
EPEORUS MAYFLIES	A	-
EPHEMERELLA MAYFLIES	A	-
EUKIEFFERIELLA TRUE MIDGES	C	-
GASTROPODA SNAILS	C	-
GLOSSOSOMATIDAE CADDISFLIES	C	-
HEPTAGENIA MAYFLIES	A	-
HETERLIMNIUS RIFFLE BEETLES	C	-
HIMALOPSYCHE CADDISFLIES	A	-
HYDROPTILA CADDISFLIES	A	-
HYDROPTILIDAE CADDISFLIES	A	-

TROPHIC LEVEL: (2) HERBIVORE
INVERTEBRATES

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
LEUCTRA STONEFLIES	Q	-
LIMNEPHILIDAE CADDISFLIES	A	-
MICRASEMA CADDISFLIES	C	-
NARPUS RIFFLE BEETLES	C	-
NEMOURA STONEFLIES	C	-
OCHROTRICHIA CADDISFLIES	A	-
OPTIOSERVUS RIFFLE BEETLES	C	-
PARALEPTOPHLEBIA AQUATIC MOTHS	C	-
PHRYGANEIDAE CADDISFLIES	A	-
PTERONARCELLA STONEFLIES	C	-
PTERONARCYS STONEFLIES	C	-
RHITHROGENA MAYFLIES	A	-
SIPHLONURUS MAYFLIES	C	-
TRICORYTHODES MAYFLIES	C	-
ZAITZEVIA RIFFLE BEETLES	C	-

Abundance codes: A=abundant, C=common, U=uncommon, Q=present abundance unknown
Status codes: R=rare, E=endangered, T=threatened, P=peripheral, I=endemic, G=game
C=commercial and potentially commercial, X=pest

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COMMUNITY COMPOSITION INLANDS ZONE: WESTERN HEMLOCK HABITAT: RIVERINE

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
TROPHIC LEVEL: (2) HERBIVORE FISHES		
CYPRINUS CARPIO CARP	A	C
LAMPETERA RICHARDSONI WESTERN BROOK LAMPREY/ AMMOCOE	A	-
TROPHIC LEVEL: (2) HERBIVORE HERPETOFAUNA		
ASCAPHUS TRUEI TAILED FROG/TADPOLE	A	-
BUFO BOREAS BOREAS NORTHWESTERN TOAD/TADPOLE	Q	-
HYLA REGILA PACIFIC TREE FROG/TADPOLE	A	-
RANA AURORA AURORA NORTHERN RED-LEGGED FROG, TADP FOOTHILL YELLOW-LEGGED FROG, T	A	-
RANA PRETIOSA SPOTTED FROG, TADPOLE	C	-
TROPHIC LEVEL: (2) HERBIVORE BIRDS		
ANAS PLATYRHYNCHOS MALLARD	U	G
BRANTA CANADENSIS CANADA GOOSE	C	G
TROPHIC LEVEL: (2) HERBIVORE MAMMALS		
CASTOR CANADENSIS BEAVER	C	C
ERITHIZON DORSATUM PORCUPINE	U	G
TROPHIC LEVEL: (3) CARNIVORE FISHES		
COTTUS ASPER PRICKLY SCULPIN	A	-
MICROPTERUS SALMOIDES LARGEMOUTH BASS	U	G
PTYCHOCHEILUS OREGONENSIS NORTHERN SQUAWFISH	C	-
SALMO CLARKI SEARUN CUTTHROAT	A	G
SALMO CLARKI CUTTHROAT TROUT	A	G
SALVELINUS MALMA DOLLY VARDEN	U	G
TROPHIC LEVEL: (3) CARNIVORE HERPETOFAUNA		
THAMNOPHIS SIRTALIS CONCINNUS RED-SPOTTED GARTER SNAKE	C	-
THAMNOPHIS SIRTALIS FITCHI VALLY GARTER SNAKE	C	
THAMNOPHIS SIRTALIS PICKERINGI PUGET SOUND RED-SIDED GARTER S	C	-

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COMMUNITY COMPOSITION INLANDS   ZONE: WESTERN HEMLOCK   HABITAT: RIVERINE

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
TROPHIC LEVEL: (3) CARNIVORE BIRDS		
ACTITIS MACULARIA SPOTTED SANDPIPER	C	-
ARDEA HERODIAS GREAT BLUE HERON	U	-
BUCEPHALA ALBEOLA BUFFLEHEAD	C	-
BUCEPHALA CLANGULA COMMON GOLDENEYE	C	-
BUTORIDES VIRESCENS GREEN HERON	U	-
HALIAEETUS LEUCOCEPHALUS BALD EAGLE	U	E
HISTRIONICUS HISTRIONICUS HARLEQUIN DUCK	U	-
LARUS ARGENTATUS HERRING GULL	U	-
LARUS CALIFORNICUS CALIFORNIA GULL	C	-
LARUS CANUS MEW GULL	U	-
LARUS DELAWARENSIS RING-BILLED GULL	C	
LARUS GLAUCESCENS GLAUCOUS-WINGED GULL	U	-
LARUS PHILADELPHIA BONAPARTE'S GULL	C	-
LARUS THAYERI THAYER'S GULL	U	-
MEGACERYLE ALCYON BELTED KINGFISHER	C	
MERGUS MERGANSER COMMON MERGANSER	U	-
PANDION HALIAETUS OSPREY	U	-
PHALACROCORAX AURITUS DOUBLE-CRESTED CORMORANT	U	-
TRINGA MELANOLEUCA GREATER YELLOWLEGS	C	-
TROPHIC LEVEL: (3) MAMMALS		
LUTRA CANADENSIS RIVER OTTER	U	-
MUSTELA VISON MINK	C	-

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
TROPHIC LEVEL: (4) DETRITIVORE INVERTEBRATES		
CERATOPOGONIDAE BITING MIDGES	C	-
DIXA DIXA MIDGES	A	-
ENCHYTRAEIDAE OLIGOCHAETS	A	-
HETEROPLECTRON CADDISFLIES	Q	-
HYDROBAENUS TRUE MIDGES	Q	-
IRONODES MAYFLIES	C	-
ISOPODA ISOPODS	C	-
LEPIDOSTOMA CADDISFLIES	A	-
LEPIDOSTOMATIDAE CADDISFLIES	A	-
LUMBRICULIDAE OLIGOCHAET	A	-
MICROTENDIPES TRUE MIDGES	-	-
MONODIAMESA TRUE MIDGES	Q	-
ODONTOMESA TRUE MIDGES	Q	-
OLIGOCHAETA SEGMENTED ROUNDWORMS	A	-
ORTHOCLADIUS TRUE MIDGES	C	-
PARAKIEFFERIELLA TRUE MIDGES	Q	-
PHAENOPSECTRA TRUE MIDGES	Q	-
PROCLADIUS TRUE MIDGES	C	-
STRATIOMYIDAE SOLDIER FLIES	C	-
TANYTARSUS TRUE MIDGES	C	-

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COMMUNITY COMPOSITION INLANDS   ZONE: WESTERN HEMLOCK   HABITAT: RIVERINE

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
TROPHIC LEVEL: (4) DETRITIVORE INVERTEBRATES		
TUBIFICIDAE TUBIFIDS	A	-
TROPHIC LEVEL: (5) OMNIVORE INVERTEBRATES		
AMPHIPODA AMPHIPODS	C	-
CLISTORONIA CADDISFLIES	Q	-
LIMNEPHILIDAE CADDISFLIES	A	-
PSYCHOGLYPHA CADDISFLIES	Q	-
TROPHIC LEVEL: (5) OMNIVORE FISHES		
CATOSTOMUS MACROCHEILUS LARGESCALE SUCKER	C	-
TROPHIC LEVEL: (5) OMNIVORE BIRDS		
AIX SPONSA WOOD DUCK	U	-
TROPHIC LEVEL: (5) OMNIVORE MAMMALS		
PROCYON LOTOR RACCOON	C	G
TROPHIC LEVEL: (6) PARASITE INVERTEBRATES		
CLIMACIA SPONGILIA	U	-
HIRUDINAE LEECHES	C	-
TROPHIC LEVEL: (6) PARASITE FISHES		
ENTOSPHENUS TRIDENTATUS PACIFIC LAMPREY	C	X
LAMPETERA AYRESI RIVER LAMPREY	C	X

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
TROPHIC LEVEL: (7) FILTER FEEDER INVERTEBRATES		
AMELETUS MAYFLIES	C	-
ARCTOPSYCHE CADDISFLIES	C	-
CERACLEA CADDISFLIES	C	-
CHEUMATOPSYCHE CADDISFLIES	A	-
COPEPODA COPEPODS	C	-
CORYNONEURA TRUE MIDGES	C	-
DIAMESA TRUE MIDGES	C	-
DOLOPHILODES -NULL-	Q	-
HETEROTRISSOCLADIUS TRUE MIDGES	Q	-
HYDROPSYCHE CADDISFLIES	A	-
KRENOSMITTIA TRUE MIDGES	Q	-
LEPTOCERIDAE CADDISFLIES	A	-
MICROPSECTRA TRUE MIDGES	C	-
MYSTACIDES CADDISFLIES	C	-
NECTOPSYCHE CADDISFLIES	Q	-
PARACLADOPELMA TRUE MIDGES	Q	-
PARACRICTOPUS TRUE MIDGES	Q	-
PARAMETRIOCNEMUS TRUE MIDGES	Q	-
PARAPSYCHE CADDISFLIES	C	-
PARATANYTARSUS TRUE MIDGES	Q	-
PELECYPODA CLAMS	C	-
PHILOPOTAMIDAE CADDISFLIES	A	-
POTTHASTIA TRUE MIDGES	C	-

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COMMUNITY COMPOSITION INLANDS ZONE: WESTERN HEMLOCK HABITAT: RIVERINE

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
TROPHIC LEVEL: (7) FILTER FEEDER INVERTEBRATES		
PSECTROCLADIUS TRUE MIDGES	C	-
PSYCHOMYIA CADDISFLIES	C	-
PSYCHOMYIIDAE CADDISFLIES	C	-
RHEOTANYTARSUS TRUE MIDGES	C	-
ROTIFERA ROTIFERS	C	-
SIMULIIDAE BLACK FLIES	A	-
SIMULIUM BLACK FLIES	Q	-
STEMPELLINA TRUE MIDGES	Q	-
STEMPELLINELLA TRUE MIDGES	Q	-
THIENEMANNIELLA TRUE MIDGES	C	-
WORMALDIA CADDISFLIES	A	-
TROPHIC LEVEL: (7) FILTER FEEDER FISHES		
ENTOSPHENUS TRIDENTATUS PACIFIC LAMPREY/ AMMOCOETES	A	-
LAMPETERA AYRESI RIVER LAMPREY/ AMMOCOETES	A	-
TROPHIC LEVEL: (8) SCAVENGER INVERTEBRATES		
ASTACIDAE CRAYFISH	C	-
TURBELLARIA FLATWORMS	C	-
TROPHIC LEVEL: (8) SCAVENGER FISHES		
ACIPENSER MEDIROSTRIS GREEN STURGEON	U	C
ACIPENSER TRANSMONTANUS WHITE STURGEON	C	C
ICTALURUS NEBULOSUS BROWN BULLHEAD	Q	-

SCIENTIFIC NAME COMMON NAME		ABUNDANCE	STATUS
TROPHIC LEVEL: (9) INVERTEBRATE EATER INVERTEBRATES			
ACRONEURIA STONEFLIES	123456789	C	-
ALLOPERLA STONEFLIES	123456789	A	-
ANSIOPTERA DRAGONFLIES	123456789	C	-
ANTHERIX SNIPE FLIES	23456789	C	-
ARCYNOPTERYX STONEFLIES	123456789	A	-
BEZZIA BITING MIDGES	23456789	Q	-
BIDESSUS AFFINIS DIVING BEETLE	123456789	C	-
CARDIOCLADIUS MIDGES	123456789	C	-
CICINDELA HIRTICOLLIS TIGER BEETLE	123456789	C	-
COLEOPTERA AQUATIC BEETLES	123456789	A	-
CORIXIDAE WATER BOATMEN	123456789	C	-
CULTUS STONEFLIES	123456789	C	-
DOLICHOPODIDAE LONG-LEGGED FLIES	123456789	C	-
DYTISCIDAE PREDACEOUS DIVING BEETLES	123456789	C	-
EMPIDIDAE DANCE FLIES	123456789	C	-
GELASTOCORIS OCULATUS TOAD BUG	123456789	C	-
GERRIDAE WATER STRIDERS	123456789	C	-
GERRIS NYCTALIS WATER STRIDER	123456789	C	-
GYRINIDAE WHIRLIGIG BEETLES	123456789	C	-
GYRINUS PICIPES WHIRLIGIG BEETLE	123456789	C	-
HYDROPHILIDAE WATER SCAVENGER BEETLES	123456789	C	-
ISOPERLA STONEFLIES	123456789	C	-
KATHROPERLA STONEFLIES	123456789	Q	-
MACROPELOPIA TRUE MIDGES	2345	Q	-

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COMMUNITY COMPOSITION INLANDS   ZONE: WESTERN HEMLOCK   HABITAT: RIVERINE

TROPHIC LEVEL: (9) INVERTEBRATE EATER
INVERTEBRATES

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
MICROVELIA BUENOI VELIID	C	-
MICROVELIA CALIFORNIENSIS VELIID	C	-
NATARSIA TRUE MIDGES	Q	-
NOTONECTIDAE BACK SWIMMERS	C	-
NYCTIOPHYLAX -NULL-	A	-
OECETIS CADDISFLIES	C	-
OMOPHRON OVALE GROUND BEETLE	U	-
PARAPERLA STONEFLIES	Q	-
POLYCENTROPODIDAE CADDISFLIES	C	-
POLYCENTROPUS CADDISFLIES	C	-
PSECTROTANYPUS TRUE MIDGES	Q	-
PTEROSTICHUS NIGROCAERULEUS GROUND BEETLE	U	-
RHYACOPHILA CADDISFLIES	C	-
RHYACOPHILIDAE CADDISFLIES	A	-
SALDULA PALLIPES SHOREBUG	C	-
SIALIS ALDERFLIES	C	-
ZYGOPTERA DAMSELFLIES	C	-
PTEROSTICHUS NIGROCAERULEUS GROUND BEETLE	U	-
SALDULA COMATULA SHOREBUG	Q	-
SALDULA PALLIPES SHOREBUG	C	-
ZICRONA CAERULEA STINK BUG	C	-

TROPHIC LEVEL: (9) INVERTEBRATE EATER
HERPETOFAUNA

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
AMBYSTOMA GRACILE GRACILE BROWN SALAMANDER	C	-
ASCAPHUS TRUEI TAILED FROG	A	-
DICAMPTODON ENSATUS PACIFIC GIANT SALAMANDER	U	-
HYLA REGILA PACIFIC TREE FROG	A	-
RANA AURORA AURORA NORTHERN RED-LEGGED FROG	U	-
RANA CATESBEIANA BULLFROG	U	-
RANA PRETIOSA SPOTTED FROG	C	-
RHYACOTRITON OLYMPICUS OLYMPIC NORTHERN OLYMPIC MOUNTAIN SALA	C	-
TARICHA GRANULOSA GRANULOSA NORTHERN ROUGH SKINNED NEWT	U	-

HABITAT: RIPARIAN

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
AMBYSTOMA GRACILE GRACILE BROWN SALAMANDER	C	-
AMBYSTOMA MACRODACTYLUM MACROD WESTERN LONG-TOED SALAMANDER	A	-
ASCAPHUS TRUEI TAILED FROG	A	-
BUFO BOREAS BOREAS NORTHWESTERN TOAD	C	-
DICAMPTODON ENSATUS PACIFIC GIANT SALAMANDER	U	-
ENSATINA ESCHSCHOLTZI OREGONEN OREGON RED SALAMANDER	U	-
GERRHONOTUS COERULEUS PRINCIPI NORTHERN ALLIGATOR LIZARD	C	-
HYLA REGILA PACIFIC TREE FROG	A	-
PLETHODON DUNNI DUNNS SALAMANDER	C	-
PLETHODON VANDYKEI WASHINGTON SALAMANDER	C	-
PLETHODON VEHICULUM WESTERN RED-BACKED SALAMANDER	C	-
RANA AURORA AURORA NORTHERN RED-LEGGED FROG	A	-

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COMMUNITY COMPOSITION INLANDS ZONE: WESTERN HEMLOCK HABITAT: RIVERINE

TROPHIC LEVEL: (9) INVERTEBRATE EATER
FISHES

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
ACIPENSER MEDIROSTRIS GREEN STURGEON / JUVENILE	U	-
ALOSA SAPIDISSMA AMERICAN SHAD	A	C
CATOSTOMUS CATOSTOMUS LONGNOSE SUCKER	C	-
COTTUS ALEUTICUS COASTRANGE SCULPIN	A	-
COTTUS GULOSUS RIFFLE SCULPIN	C	-
GASTEROSTEUS ACULEATUS THREESPINE STICKLEBACK	A	-
LEPOMIS MACROCHIRUS BLUEGILL	C	G
MYLOCHEILUS CAURINUS PEAMOUTH	C	-
ONCORHYNCHUS KETA CHUM SALMON/ FRY	U	-
ONCORHYNCHUS KISUTCH COHO SALMON/ FRY	A	C
ONCORHYNCHUS NERKA SOCKEYE SALMON	U	C
ONCORHYNCHUS NERKA KOKANEE	C	C
ONCORHYNCHUS TSHAWYTSCHA CHINOOK SALMON/ JUVENILE	A	C
RHINICHTHYS CATARACTAE LONGNOSE DACE	C	-
RHINICHTHYS OSCULUS SPECKLED DACE	C	-
RICHARDSONIUS BALTEATUS REDSIDE SHINER	A	-
SALMO GAIRDNERI STEELHEAD TROUT	C	G
SALMO GAIRDNERI RAINBOW TROUT	A	G

TROPHIC LEVEL: (9) INVERTEBRATE EATER
BIRDS

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
CHARADRIUS VOCIFERUS KILLDEER	U	-
CINCLUS MEXICANUS DIPPER	C	-

TROPHIC LEVEL: (9) INVERTEBRATE EATER
MAMMALS

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
EPTESICUS FUSCUS BIG BROWN BAT	C	-
MYOTIS YUMANENSIS YUMA MYOTIS	C	-

TROPHIC LEVEL: (0)
INVERTEBRATES

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
PHILOCASCA CADDISFLIES	Q	-
PLECOPTERA STONEFLIES	A	-
PSEPHENIDAE WATER PENNIES	U	-
PSYCHODIDAE MOTH FLIES	A	-
PTILODACTYLIDAE PTILODACTYL BEETLES	Q	-
RHEOCRICOTOPUS TRUE MIDGES	C	-
SERICOSTOMATIDAE CADDISFLIES	A	-
THIENEMANNIMYIA TRUE MIDGES	Q	-
TIPULIDAE CRANE FLIES	A	-
TRIAENODES CADDISFLIES	Q	-
TRICHOPTERA CADDISFLIES	A	-
ACARINA WATER MITES	A	-
CHIRONOMUS TRUE MIDGES	A	-
CLOSTOECA CADDISFLIES	Q	-
CONCHAPELOPIA TRUE MIDGES	Q	-
DICOSMOECUS CADDISFLIES	C	-
ECCLISOMYIA CADDISFLIES	C	-
EPHEMEROPTERA MAYFLIES	A	-

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COMMUNITY COMPOSITION INLANDS ZONE: WESTERN HEMLOCK HABITAT: RIVERINE

TROPHIC LEVEL: (O)
INVERTEBRATES

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
GOERA CADDISFLIES	Q	-
GRAMMOTAULIS CADDISFLIES	Q	-
HALESOCHILA CADDISFLIES	Q	-
HELICOPSYCHE CADDISFLIES	C	-
HOMOPHYLAX CADDISFLIES	U	-
HYDATOPHYLAX CADDISFLIES	Q	-
HYDROPSYCHIDAE CADDISFLIES	A	-
LENARCHUS CADDISFLIES	Q	-
LIMNEPHILUS CADDISFLIES	A	-
MOSELYANA CADDISFLIES	Q	-
MUSCIDAE HOUSE FLIES	C	-
NEMATODA ROUNDWORMS	C	-
NEMATOMORPHA HORSEHAIR WORMS	Q	-
NEMOTAULUS CADDISFLIES	Q	-
NEOPHYLAX CADDISFLIES	C	-
OSTRACODA SEED SHRIMP	C	-
PELTOPERLA STONEFLIES	C	-

TROPHIC LEVEL: (O)
FISHES

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
COTTUS PERPLEXUS RETICULATE SCULPIN	C	-
LAMPETERA RICHARDSONI WESTERN BROOK LAMPREY	U	-
ONCORHYNCHUS GORBUSCHA PINK SALMON	U	C
ONCORHYNCHUS KETA CHUM SALMON	U	C
ONCORHYNCHUS KISUTCH COHO SALMON	C	C
ONCORHYNCHUS TSHAWYTSCHA CHINOOK SALMON	A	C

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APPENDIX B

COMMUNITY COMPOSITION - RIPARIAN HABITAT

COMMUNITY COMPOSITION INLANDS   ZONE: WESTERN HEMLOCK   HABITAT: RIPARIAN

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
TROPHIC LEVEL: (1) PRODUCER VASCULAR PLANTS		
ALNUS RUBRA RED ALDER	A	C
ATHYRIUM FELIX-FEMINA LADY FERN	C	-
BOYKINIA ELATA COAST BOYKINIA	U	-
CAREX DEWEYANA DEWEY SEDGE	C	-
DICENTRA CUCULLARIA DUTCHMAN'S BREECHES	U	R
EQUISETUM ARVENSE COMMON HORSETAIL	A	-
EQUISETUM HYEMALE SCOURING-RUSH	A	-
ERYTHRONIUM REVOLUTUM GLACIER-LILY	U	R
FILIPENDULA OCCIDENTALIS FILIPENDULA	U	R
FRAXINUS LATIFOLIA OREGON ASH	C	-
ISOETES NUTTALLII NUTTALL'S QUILLWORT	U	R
JUNCUS SUPINIFORMIS SPREADING RUSH	U	R
LOTUS CRASSIFOLIUS THICK-LEAVED LOTUS	U	-
MENZIESIA FERRUGINEA RUSTYLEAF	U	-
MIMULUS GATTATUS YELLOW MONKEYFLOWER	U	-
OPLOPLANAX HORRIDUM DEVILSCLUB	A	-
OXALIS OREGANA OREGON OXALIS	U	-
PLEUROPOGON REFRACTUS NODDING SEMAPHORE GRASS	U	R
POPULUS TRICHOCARPA BLACK COTTONWOOD	A	-
RIBES GOOSEBERRY	C	-
RORIPPA NASTURTIUM AQUATICUM WATER - CRESS	C	-
RUBUS DISCOLOR HIMALAYAN BLACKBERRY	U	-
RUBUS LACINIATUS EVERGREEN BLACKBERRY	U	-
SALIX WILLOW	A	-
SALIX FLUVIATILIS COLUMBIA RIVER WILLOW	U	R
SYMPHORICARPOS ALBUS COMMON SNOWBERRY	U	-
VERATRUM VIRIDE FALSE HELLEBORE	U	-
WOODWARDIA FIMBRIATA CHAIN FERN	U	R

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COMMUNITY COMPOSITION INLANDS   ZONE: WESTERN HEMLOCK   HABITAT: RIPARIAN

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
TROPHIC LEVEL: (2) HERBIVORE INVERTEBRATES		
ALTICA AMBIENS ALDER FLEA BEETLE	C	X
ARIOLIMAX COLUMBIANUS BANANA SLUG	A	X
ARION ATER BLACK SLUG	C	X
CORYTHUCHA PERGANDEI LACEBUG	Q	-
HAPLOTREMA SPORTELLA SNAIL	Q	-
HAPLOTREMA VANCOUVERENSE SNAIL	Q	-
HEMPHILLIA SLUG	C	X
HYPHANTRIA CUNEA FALL WEBWORM	C	X
LEPERISINUS CALIFORNICUS BARK BEETLE	C	X
LEPERISINUS OREGONUS BARK BEETLE	C	X
LEUCOMA SALICIS TUSSOCK MOTH	C	X
MALACOSOMA DISSTRIA FOREST TENT CATERPILLAR	C	X
NEMATUS CURRENI SAWFLY	C	-
ORTHOTYLUS PLANT BUG	C	-
PROPHYSAON ANDERSONI SLUG	C	X
PSEUDOHYLESINUS NOBILIS BARK BEETLE	C	X
PYRRHALTA DECORA CARBO PACIFIC WILLOW LEAF BEETLE	C	X
STENODEMA TRISPINOSUM PLANTBUG	C	-
TETTNIX PYGMY GRASSHOPPERS	C	-
TROPIDOSTEPTES PACIFICUS PLANT BUG	C	X
VESPERCULA COLUMBIANUS SNAIL	Q	-

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
TROPHIC LEVEL: (2) HERBIVORE BIRDS		
BOMBYCILLA CEDRORUM CEDAR WAXWING	C	-
BOMBYCILLA GARRULUS BOHEMIAN WAXWING	U	-
BONASA UMBELLUS RUFFED GROUSE	C	-
CARDUELIS FLAMMEA COMMON REDPOLL	U	-
CARDUELIS PINUS PINE SISKIN	C	-
CARDUELIS PSALTRIA LESSER GOLDFINCH	C	-
CARDUELIS TRISTIS AMERICAN GOLDFINCH	C	-
CARPODACUS MEXICANUS HOUSE FINCH	C	-
CARPODACUS PURPUREUS PURPLE FINCH	C	-
CATHARUS GUTTATUS HERMIT THRUSH	C	-
CATHARUS USTULATUS SWAINSON'S THRUSH	C	-
HESPERIPHONA VESPERTINA EVENING GROSBEAK	C	-
IXOREUS NAEVIUS VARIED THRUSH	C	-
JUNCO HYEMALIS DARK-EYED JUNCO	C	-
LOPHORTYX CALIFORNICUS CALIFORNIA QUAIL	C	-
MELOSPIZA MELODIA SONG SPARROW	C	-
PASSERELLA ILIACA FOX SPARROW	C	-
PASSERINA AMOENA LAZULI BUNTING	C	-
PHEUCTICUS MELANOCEPHALUS BLACK-HEADED GROSBEAK	C	-
PIPILO ERYTHROPHTHALMUS RUFOUS-SIDED TOWHEE	C	-
SELASPHORUS RUFUS RUFOUS HUMMINGBIRD.	C	-
SPIZELLA ARBOREA TREE SPARROW	U	P
STURNUS VULGARIS STARLING	C	-
ZONOTRICHIA ATRICAPILLA GOLDEN- CROWNED SPARROW	C	-
ZONOTRICHIA LEUCOPHRYS WHITE-CROWNED SPARROW	C	-

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COMMUNITY COMPOSITION INLANDS   ZONE: WESTERN HEMLOCK   HABITAT: RIPARIAN

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
TROPHIC LEVEL: (2) HERBIVORE MAMMALS		
APLODONTIA RUFA MOUNTAIN BEAVER	C	-
ARBORIMUS ALBIPES WHITE-FOOTED VOLE	U	R
CASTOR CANADENSIS BEAVER	C	C
CERVUS CANADENSIS ROOSEVELT ELK	C	G
CLETHRIONOMYS OCCIDENTALIS WESTERN RED-BACKED VOLE	U	-
ERITHIZON DORSATUM PORCUPINE	U	G
LEPUS AMERICANUS SNOWSHOE HARE	C	G
MICROTUS LONGICAUDUS LONG-TAILED VOLE	U	-
MICROTUS OREGONI OREGON VOLE	C	-
NEOTOMA CINEREA BUSHY-TAILED WOOD RAT	U	-
NEOTOMA FUSCIPES DUSKY-FOOTED WOOD RAT	C	P
ODOCOILEUS HEMIONUS COLUMBIANU BLACK-TAILED DEER	C	G
ODOCOILEUS VIRGINIANUS WHITE-TAILED DEER	U	E
ONDATRA ZIBETHICA MUSKRAT	U	C
SYLVILAGUS FLORIDANUS EASTERN COTTONTAIL	C	G
TAMIASCIURUS DOUGLASII DOUGLAS SQUIRREL	U	G

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
TROPHIC LEVEL: (3) CARNIVORE HERPETOFAUNA		
CHARINA BOTTAE PLUMBEA PACIFIC RUBBER BOA	C	-
DIADOPHIS PUNCTATUS OCCIDENTAL NORTHWESTERN RINGNECK SNAKE	C	-
THAMNOPHIS SIRTALIS CONCINNUS RED-SPOTTED GARTER SNAKE	A	-
THAMNOPHIS SIRTALIS FITCHI VALLY GARTER SNAKE	A	-
THAMNOPHIS SIRTALIS PICKERINGI 123 PUGET SOUND RED-SIDED GARTER S	A	-

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C=commercial and potentially commercial, X=pest

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COMMUNITY COMPOSITION INLANDS   ZONE: WESTERN HEMLOCK   HABITAT: RIPARIAN

TROPHIC LEVEL: (3) CARNIVORE
BIRDS

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
ACCIPITER COOPERII COOPER'S HAWK	U	-
ACCIPITER STRIATUS SHARP-SHINNED HAWK	U	-
ACTITIS MACULARIA SPOTTED SANDPIPER	U	-
AEGOLIUS ACADICUS SAW-WHET OWL	U	-
ARDEA HERODIAS GREAT BLUE HERON	C	-
ASIO OTUS LONG-EARED OWL	U	-
BUBO VIRGINIANUS GREAT HORNED OWL	C	-
BUTEO JAMAICENSIS RED-TAILED HAWK	C	-
BUTORIDES VIRESCENS GREEN HERON	U	-
CORVUS CORAX COMMON RAVEN	C	-
FALCO COLUMBARIUS MERLIN	U	-
FALCO SPARVERIUS AMERICAN KESTREL	U	-
HALIAEETUS LEUCOCEPHALUS BALD EAGLE	U	E
LANIUS EXCUBITOR NORTHERN SHRIKE	U	-
NYCTICORAX NYCTICORAX BLACK-CROWNED NIGHT HERON	U	-
PANDION HALIAETUS OSPREY	U	-
TYTO ALBA BARN OWL	U	-

TROPHIC LEVEL: (G)
MAMMALS

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
LYNX RUFUS BOBCAT	C	-

TROPHIC LEVEL: (C)
MAMMALS

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
LUTRA CANADENSIS RIVER OTTER	U	-
MUSTELA VISON MINK	C	-

TROPHIC LEVEL: (3) CARNIVORE
MAMMALS

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
CANIS LATRANS COYOTE	C	G
FELIS CONCOLOR MOUNTAIN LION	U	G
MUSTELA ERMINEA SHORT-TAILED WEASEL	U	C
MUSTELA FRENATA LONG-TAILED WEASEL	C	G
SOREX OBSCURUS DUSKY SHREW	C	-
SPILOGALE PUTORIUS SPOTTED SKUNK	C	G
UROCYON CINEREOARGENTEUS GRAY FOX	C	G
VULPES FULVA RED FOX	U	P

TROPHIC LEVEL: (5) OMNIVORE
BIRDS

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
CORVUS BRACHYRHYNCHOS COMMON CROW	C	-

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COMMUNITY COMPOSITION INLANDS   ZONE: WESTERN HEMLOCK   HABITAT: RIPARIAN

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
TROPHIC LEVEL: (5) OMNIVORE MAMMALS		
BASSARISCUS ASTUTUS RINGTAIL	U	R
DIDELPHIS MARSUPIALIS COMMON OPOSSUM	U	G
EUARCTOS AMERICANUS BLACK BEAR	C	G
EUTAMIAS TOWNSENDII TOWNSEND'S CHIPMUNK	C	-
GLAUCOMYS SABRINUS NORTHERN FLYING SQUIRREL	C	-
MEPHITIS MEPHITIS STRIPED SKUNK	C	-
MUS MUSCULUS HOUSE MOUSE	U	X
PEROMYSCUS MANICULATUS DEER MOUSE	A	X
PROCYON LOTOR RACCOON	C	G
RATTUS RATTUS BLACK RAT	U	X
SPERMOPHILUS BEECHEYI CALIFORNIA GROUND SQUIRREL	C	X
ZAPUS TRINOTATUS PACIFIC JUMPING MOUSE	C	-

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
TROPHIC LEVEL: (8) SCAVENGER BIRDS		
CATHARTES AURA TURKEY VULTURE	U	-

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COMMUNITY COMPOSITION INLANDS ZONE: WESTERN HEMLOCK HABITAT: RIPARIAN

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
TROPHIC LEVEL: (9) INVERTEBRATE EATER INVERTEBRATES		
CICINDELA HIRTICOLLIS TIGER BEETLE	C	-
CORYTHUCHA SALICATA WESTERN WILLOW LACEBUG	Q	-
DERAEOCORIS TSUGAE PLANT BUG	C	-
DERAEOCORIS VALIDUS PLANT BUG	C	-
MICROVELIA BUENOI VELIID	C	-
MICRUVELIA CALIFORNIENSIS VELIID	C	-
OMOPHRON OVALE GROUND BEETLE	C	-
TROPHIC LEVEL: (9) INVERTEBRATE EATER HERPETOFAUNA		
RANA CATESBEIANA BULLFROG	C	-
RANA PRETIOSA SPOTTED FROG	C	-
RHYACOTRITON OLYMPICUS OLYMPIC NORTHERN OLYMPIC MOUNTAIN SALA	C	-
TARICHA GRANULOSA GRANULOSA NORTHERN ROUGH SKINNED NEWT	C	-

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
TROPHIC LEVEL: (9) INVERTEBRATE EATER BIRDS		
AGELAIUS PHOENICEUS RED-WINGED BLACKBIRD	C	-
CERTHIA FAMILIARIS BROWN CREEPER	U	-
CHAETURA VAUXI VAUX'S SWIFT	C	-
CHAMAEA FASCIATA WRENTIT	C	-
CINCLUS MEXICANUS DIPPER	U	-
CISTOTHORUS PALUSTRIS LONG-BILLED MARSH WREN	C	-
COCCYZUS AMERICANUS YELLOW-BILLED CUCKOO	U	P
COLAPTES AURATUS COMMON FLICKER	C	-
CONTOPUS SORDIDULUS WESTERN WOOD PEWEE	U	-
DENDROCOPOS PUBESCENS DOWNY WOODPECKER	C	-
DENDROICA CORONATA YELLOW-RUMPED WARBLER	U	-
DENDROICA PETECHIA YELLOW WARBLER	C	-
DRYOCOPUS PILEATUS PILEATED WOODPECKER	U	-
EMPIDONAX DIFFICILIS WESTERN FLYCATCHER	U	-
EMPIDONAX TRAILLI WILLOW FLYCATCHER	C	-
HIRUNDO RUSTICA BARN SWALLOW	A	-
ICTERUS GALBULA NORTHERN ORIOLE	C	-
IRIDOPROCNE BICOLOR TREE SWALLOW	C	-
MELANERPES LEWIS LEWIS WOODPECKER	U	-
MOLOTHRUS ATER BROWN-HEADED COWBIRD	C	-
MYADESTES TOWNSENDI TOWNSEND'S SOLITAIRE	U	-
OTUS ASIO SCREECH OWL	C	-

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COMMUNITY COMPOSITION INLANDS   ZONE: WESTERN HEMLOCK   HABITAT: RIPARIAN

TROPHIC LEVEL: (9) INVERTEBRATE EATER
BIRDS

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
REGULUS CALENDULA RUBY-CROWNED KINGLET	C	-
REGULUS SATRAPA GOLDEN-CROWNED KINGLET	C	-
RIPARIA RIPARIA BANK SWALLOW	U	-
SITTA CANADENSIS RED-BREASTED NUTHATCH	U	-
SPHYRAPICUS VARIUS YELLOW-BELLIED SAPSUCKER	U	-
STELGIDOPTERYX RUFICOLLIS ROUGH-WINGED SWALLOW	C	-
TACHYCINETA THALASSINA VIOLET-GREEN SWALLOW	C	-
THYROMANES BEWICKII BEWICK'S WREN	C	-
TROGLODYTES AEDON HOUSE WREN	U	-
TROGLODYTES TROGLODYTES WINTER WREN	C	-
TURDUS MIGRATORIUS ROBIN	C	-
TYRANNUS VERTICALIS WESTERN KINGBIRD	U	-
VERMIVORA CELATA ORANGE-CROWNED WARBLER	C	-
VERMIVORA RUFICAPILLA NASHVILLE WARBLER	C	-
VIREO GILVUS WARBLING VIREO	C	-
VIREO OLIVACEUS RED-EYED VIREO	C	-
WILSONIA PUSILLA WILSON'S WARBLER	C	-
PARUS ATRICAPILLUS BLACK-CAPPED CHICKADEE	C	-
PARUS RUFESCENS CHESTNUT-BACKED CHICKADEE	C	-
PETROCHELIDON PYRRHONOTA CLIFF SWALLOW	C	-
PIRANGA LUDOVICIANA WESTERN TANAGER	C	-

TROPHIC LEVEL: (9) INVERTEBRATE EATER
MAMMALS

SCIENTIFIC NAME COMMON NAME	ABUNDANCE	STATUS
EPTESICUS FUSCUS BIG BROWN BAT	C	-
LASIONYCTERIS NOCTIVAGANS SILVER-HAIRED BAT	U	-
LASIURUS CINEREUS HOARY BAT	U	-
MYOTIS CALIFORNICUS CALIFORNIA MYOTIS	C	-
MYOTIS EVOTIS LONG-EARED MYOTIS	U	-
MYOTIS KEENII KEEN MYOTIS	U	P
MYOTIS LUCIFUGUS LITTLE BROWN MYOTIS	C	-
MYOTIS THYSANODES FRINGED MYOTIS	U	-
MYOTIS VOLANS LONG-LEGGED MYOTIS	U	-
MYOTIS YUMANENSIS YUMA MYOTIS	C	-
NEUROTRICHUS GIBBSII SHREW-MOLE	A	-
SCAPANUS ORARIUS COAST MOLE	C	-
SOREX BENDIRII MARSH SHREW	C	-
SOREX TROWBRIDGII TROWBRIDGE SHREW	C	-
SOREX VAGRANS VAGRANT SHREW	U	-

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16. Abstract (Limit: 200 words)

High, medium, and low probabilities of energy related development are projected for the Columbia River Estuary to river mile 93. Projections for five, fifteen, and twenty-five year planning horizons are aggregated, mapped, and described. The direct and indirect effects of projected energy-related development upon fish and wildlife in estuarine and riverine systems are summarized. Habitats affected by construction are identified, and operations of energy facility components causing impacts are characterized. Ecosystem models are developed for riverine, estuarine, channel, sandflat, mudflat, emergent vegetation, and riparian habitats to determine biological significance and pathways of projected impacts. Species accounts are furnished for 13 species and species groups that are of special concern. Cumulative impacts are integrated and described on a site-specific basis Policy-making, planning, and regulatory processes relevant to the control of energy-related impacts in the Columbia River Estuary and lower river are outlined. Management and mitigation measures are discussed both for species of concern and for the types of energy facilities expected to be developed.

17. Document Analysis a. Descriptors

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DEPARTMENT OF THE INTERIOR
U.S. FISH AND WILDLIFE SERVICE

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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